WEST AFRICAN CACAO RESEARCH INSTITUTE

ANNUAL REPORT

April, 1947 to March, 1948

TAFO, GOLD COAST

Published on behalf of the West African Cacao Research Institute by the Crown Agents for the Colonies, 4, Millbank, London, S.W.1.

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WEST AFRICAN CACAO RESEARCH INSTITUTE.

SENIOR STAFF LIST AS AT MARCH 31st, 1948,

Director	O. J. Voelcker, M.A., A.I.C.T.A.
Principal Research Officer	J. West, B.S.A., A.I.C.T.A.
Division of Entomology	J. Nicol, B.Sc. (For.), A.R.P.S. R. G. Donald, B.Sc., A.I.C.T.A., F.R.E.S. G. Williams, B.Sc., A.I.C.T.A. A. J. P. Goodchild, B.Sc., D.I.C., F.R.E.S. F. E. Decker, Assistant Specialist.
Division of Pathology and Botany.	A. F. Posnette, M.A., A.I.C.T.A. A. H. Strickland, M.A., A.I.C.T.A., F.R.E.S. J. McA. Todd, B.Sc., A.I.C.T.A. H. Owen, B.Sc., A.I.C.T.A. N. F. Robertson, B.Sc., Dip. Ag. Sc. H. Evans (Horticulturist).
Division of Soil Science and Chemistry.	C. F. Charter, M.A. J. A. R. MacLean, B.Sc., Ph.D., A.R.I.C. T. Wasowicz, Ph.D., A.R.I.C.
Division of Agronomy ...	R. J. Benstead, N.D.A., C.D.A.
Secretary	G. H. Neal, F.R.S.A.
Construction Engineer ...	Major C. Alderson, D.S.O., E.D., B.Sc., M.Inst.M. and C.E.

WEST AFRICAN CACAO RESEARCH INSTITUTE.
ANNUAL REPORT : 1st APRIL, 1947 TO 31st MARCH, 1948.

SECTION I.

POLICY AND ORGANIZATION.

THE MANAGING COMMITTEE.

During the period under review the Institute ceased to remain under the immediate control of the West African Council and has been managed by a committee. Membership of the committee is as follows :—

The Chairman,	nominated	by	the	Secretary of State.
Four members,	,,	,,	,,	Governor of the Gold Coast.
Four members,	,,	,,	,,	Governor of Nigeria.
The Director,	,,	,,	,,	Secretary of State.

To assist in the Committee's deliberations additional non-voting members have been appointed.

Owing to a number of circumstances the first meeting, under the Chairmanship of Mr. W. B. L. Monson, Chief Secretary to the West African Council, was not held until 10th December, 1947. The meeting, lasting three days, took place at Tafo to allow members to acquaint themselves with the work in progress and with the plans for development. Attention was focussed on the fact that funds available to the Institute would be insufficient to finance the programme of research for the 20 years originally envisaged when the £1¼ million were allocated. It was pointed out that research on the selection and breeding of cacao, on fundamental cultivation problems and on certain aspects of diseases and pests was of a long term nature. The Committee agreed that every effort should be made to finance the Institute for the full period of 20 years; methods by which this could be done are now under consideration. Estimates of Capital Expenditure, inflated by recent increased costs of material and labour, were approved after critical examination. These estimates have now also been approved by the Secretary of State.

A General Purposes Sub-Committee consisting of three members was appointed to deal with questions of administration beyond the power of the Director to decide. To ensure speedy decisions it was considered advisable to appoint only those members of the Committee stationed near Accra. Decisions on matters affecting pensionable staff have formed the largest proportion of the Sub-Committee's work.

The second meeting of the Managing Committee took place at Tafo on 12th February, 1948. Among other matters discussed the Committee considered and approved the Recurrent Estimates for the year 1948/49. The Nigerian representatives drew attention to the heavy losses through pod diseases suffered during 1947 and asked

whether the Institute could arrange for research to be undertaken in Nigeria on pod disease control. As a result of this request steps are being taken to provide additional W.A.C.R.I. pathological staff.

It is early yet to assess the full effects of the legislation under which the Institute and its Managing Committee have been constituted. In general the new method of management of the Institute's financial and administrative affairs has worked smoothly. Certain difficulties have, however, arisen through specific clauses of the Ordinance. For example, members of the Managing Committee are nominated by name. In the event of a nominee being absent from West Africa on leave, his place can only be taken by a non-voting member. Of less importance, but indicative of the troubles to which a too detailed legislation may lead, is the clause permitting the use of the Official Seal only after a resolution has been duly passed by the full Committee. As the Committee only meets twice a year use of the Seal can rarely be made. On financial matters, particularly in connection with expenditure, the Managing Committee agreed that it was essential to include all members in a Finance Sub-Committee, the quorum of which being, however, smaller than that required for the full Committee. It is unfortunate, and apparently inevitable, that contact with all members of the Finance Sub-Committee, *i.e.*, the full Committee, involves considerable delay in spite of the improved air services between the Gold Coast and Nigeria.

The Director is indebted to members of the Managing Committee for the helpful advice given and decisions taken by them.

CONSTRUCTION.

During 1947 construction was for the most part held up pending consideration of the revised estimates of Extraordinary Expenditure by the Managing Committee. With the approval of these estimates the tempo of construction has increased. Apart from minor works, the Institute proposes to build quarters for the majority of its Junior Staff, permanent houses to replace the temporary structures now occupied by Senior Staff, an administrative block and to install a pipe-borne water system.

The construction schedule is as follows :—

	Approved.	Under construction or completed.
Administrative Block	1	—
Junior Staff.		
Four-room Houses ...	10	—
Three-room Houses ...	50	6
Two-room Double Units...	62	39
Recreation Hall	1	—
Senior Staff.		
Bungalows...	13	5

Pipe-borne Water.

The dam site is being explored ; pipes, pumps and filtration plant are on order.

The supply of construction material is now becoming slightly easier, and it is hoped that considerable progress will be made during the next twelve months. The buildings are being put up by contract under the general supervision of the Construction Engineer.

London Cacao Conference.

At the invitation of the Cocoa, Chocolate and Confectionery Alliance Limited, the Director and Mr. A. F. Posnette attended a conference held in London on 3rd-5th September, 1947. The Conference afforded an opportunity for a full discussion on the type of cacao required by the manufacturing industry, the present supply position—made acute through diseases and pests of cacao trees—and on the progress of research designed to increase production. It was understandable, but none the less gratifying, to learn of the keen interest taken not only by the cocoa manufacturing industry, but also by H.M. Government, in the activities of this Institute and of the cacao research scheme in the West Indies.

The report of the Proceedings of the Conference has been published.

Senior Staff Changes.

On 1st April, 1948, the Senior Staff numbered 16, one of whom is a temporary appointment and expected to leave shortly. In order to complete the approved establishment of 20, there are, therefore, to be filled four immediate vacancies, soon to be increased to five. In addition to the establishment there are two supernumerary posts—a construction engineer and a pathologist for work on pod diseases in Nigeria. The former has been filled and there are good prospects for filling the latter.

At a time when qualified scientific staff is in so short supply the Institute is fortunate in having three-quarters of its establishment filled. Nevertheless there is only one agronomist and no full-time plant breeder. Until staff is appointed, work on cacao breeding and on improved methods of growing cacao must of necessity hang fire. An additional lacuna has been caused by the resignation of Dr. D. W. Goodall, Plant Physiologist, who has recently taken an appointment at Melbourne University.

Mr. D. J. Billes, Entomologist, and Mr. D. Westwood, Agronomist, have completed their three-year term of secondment from the Gold Coast Department of Agriculture, to which they have returned.

Mr. C. F. Charter, Senior Soil Scientist, transferred on 1st April, 1948, to the Gold Coast Department in order to carry out the Soil Survey of the forest belt.

During the year two new appointments have been made. Mr. A. J. P. Goodchild, Entomologist, replaces Mr. Billes, and Dr. T. Wasowicz, Soil Scientist, is studying soil fertility problems in connection with cacao.

The Junior Pensionable Establishment is 55, which includes Clerical and Accounting Assistants. Considerable difficulty has been experienced in recruiting Junior staff for the Soil Science and Chemistry Division. Some knowledge of Chemistry is of course essential but applicants with this qualification are few and far between.

Scholarships.

The question of scholarships was raised both at the First and Second Meetings of the Managing Committee. It was agreed that two types of scholarships should be offered by W.A.C.R.I. to Africans; the first would provide for attendance at Universities in the United Kingdom to allow scholars to obtain the graduate and post-graduate qualifications necessary for appointment to the Senior Staff, the second type of scholarship would provide laboratory training to increase the technical ability of the Junior establishment. Financial provision has been made in the 1948/49 estimates for both types of scholarship, but at present it is uncertain whether arrangements can in fact be made for scholars to obtain laboratory training in the United Kingdom.

Non-Pensionable Junior Staff.

The Institute has adopted as far as possible the increased salary scales and new terms of service introduced by the Gold Coast Government for the benefit of unestablished and daily paid staff. The new scales are, however, far from simple, and it is unlikely that anomalies will be rectified in the immediate future. There is a danger that strict adherence to the new scales, even if this were possible, might lead to a lack of flexibility and consequent loss of efficiency. In any event the Institute will have to make greatly increased financial provision for the salaries of the non-pensionable staff.

Organization.

The new internal organization whereby Divisional Heads are allocated annually fixed sums and are responsible for the detailed expenditure under Labour, Equipment, Transport and Travelling has worked smoothly.

Putting into effect the new salary scales and revised terms of service for the pensionable staff (Harragin Commission) and similar revisions for the non-pensionable staff (Korsah Commission) has thrown greatly increased work on the Accounts and Personnel branch. The Accounts branch has further had to deal with increased work in connection with the large sums involved in the Institute's Capital Expenditure.

Systems of internal audit have been introduced by the Secretary and have proved of value.

A Junior staff Committee was elected to advise on the design of Junior staff quarters and on the best method of utilizing the sums allocated to recreational facilities. A Junior staff Canteen has also been in operation. No doubt the functions of the Committee will in due course be absorbed into the proposed Whitley Councils.

A Senior staff Resident's Council has been functioning during the year and has made useful suggestions on such matters as house and furniture design and on improved amenities to living conditions at Tafo.

Finance.

The system whereby the Institute has been financed by advances from the Gold Coast Government against periodic reimbursements from the funds held by the Crown Agents on behalf of the Institute ceased on 31st March, 1948. Thereafter it is proposed that the Institute, authorized by the Managing Committee, should draw directly from the funds held by the Crown Agents. This will mean that the Institute will have to maintain an appreciable balance in its current account with the local bank. The Institute's funds with the Crown Agents amount to some £897,000 as at 31st March, 1948.

The opportunity is now taken of again expressing thanks to the Gold Coast Government for having been most helpful over the past four years in the mechanics of financing the Institute.

In order adequately to provide for the full programme of research over a 20-year period it is estimated that an additional £1 million will be required.

Recurrent Expenditure during the Financial Year 1947/48 was appreciably less than the estimates. This was mainly due to the impossibility of filling the Senior staff establishment. But very strict economies have also played their part in reducing expenditure.

Groundnut Soil Survey.

The Institute loaned to the Gold Coast Government the services of the Senior Soil Scientist and many of his Junior staff to conduct Soil Surveys of possible groundnut areas. The preliminary surveys have been completed. The surveys themselves and the preparation of reports thereon involved some four months' work.

Health.

The Antimalarial Control measures have continued to prove most effective, and the health of the Senior staff, wives and children has been good. The Dispensary has, however, reported a high incidence of Malaria among the Junior staff and it is hoped that this will decrease when the Junior staff occupies the new quarters; these will, of course, receive the routine D.D.T. spray.

Swollen Shoot.

A considerable amount of time has been spent by the Senior staff in explaining and demonstrating the control of swollen shoot disease. Technical evidence has been given before committees in Accra and elsewhere and parties of Chiefs, pressmen, members of the Legislative Council and head farmers have been shown the Institute's work on swollen shoot at Tafo. On the old part of the Institute's land control by cutting out has been practised since 1940; the cacao here is demonstrably better than on the farmers' land adjoining where no control measures have been adopted. Unfortunately this scientific evidence is unpalatable to those who are politically opposed to the method of control by cutting out, which is the only proved recommendation that can be given.

Political Disturbances.

The disturbances which spread from Accra reached Tafo on 1st March, 1948. During a period of considerable excitement stores in the village were looted. It was considered advisable to evacuate the women and children to Accra, whence they returned on 13th March. The Institute suffered no material damage and both the Senior and Junior staff are to be congratulated on having maintained discipline and steadiness. It was feared that the Institute might have been the target of those who wished forcibly to express their dissatisfaction with the policy of cutting out swollen shoot diseased trees.

Acknowledgements.

It is again the Director's duty and privilege to accord thanks to the Divisional Heads, who, with the specialist staff, have prepared the technical information presented in this report.

The Institute has continued to receive helpful advice from leading scientists in the United Kingdom and no acknowledgement would be complete without recognition of the co-operation afforded by the Departments of Agriculture, Gold Coast and Nigeria.

SECTION II.

VIRUS RESEARCH.

Swollen Shoot and other Virus Diseases of Cacao.

1. *A New Cacao Virus ?*

In the course of the Nigerian survey in 1946, a patch of dying cacao was discovered near Asalu in the Abeckuta district. Symptoms were present on the leaves as bright, transparent, often distorted lesions distributed fairly evenly on either side of the midrib or main lateral veins. No swellings were found on the trees. Later in the year a second outbreak with similar symptoms was discovered near Sechodumasi in Ashanti. The Asalu virus has been transmitted by grafting at Tafo, but not yet by any of the vectors of swollen shoot. This fact, considered with the distinctive leaf symptoms and the absence of swellings, suggests that this virus is quite unrelated to the other cacao viruses known in West Africa. It fails to protect against the Kpeve virus (strain C), which it resembles in not producing swellings.

2. *The Western Province Viruses.*

In November, 1946, budwood was collected from outbreaks in different localities within a 15-mile radius of Wiawso; sometimes budwood was taken from several trees in an outbreak if it was thought that more than one virus was present. In all, 33 collections were made and from each collection five Amelonado seedlings were inoculated by patch grafting. The symptoms on each flush of these test plants were recorded for a subsequent period of 15 months and by this means the several viruses could be distinguished and their characteristic symptom sequences described.

The grafting tests served to corroborate most of the impressions gained in the field. They proved that many viruses with different symptoms are present in this area and also that striking differences in symptoms occur between the viruses of adjacent outbreaks. Variation within outbreaks was also demonstrated but this tended to be rather less perceptible. The viruses have been divided according to leaf symptoms into four major classes within which further separation depends on finer differences in symptom expression. The scheme is given in Table 1.

Bright yellow chlorosis is a strikingly common feature of many of these viruses—it occurs in three of the four symptom classes mentioned above. The characteristic cloudy yellow mottle of the "yellows" and "clearings" classes is very conspicuous in the outbreaks. Outside the Wiawso district it is characteristic of the Pamen virus (E) and has been noted as an occasional symptom with

one of the Nigerian viruses but is otherwise very uncommon. This type of yellowing is extraordinary in that it becomes conspicuous only some time after the leaf has hardened and is usually preceded by scattered lengths of greenish or yellowish fine vein banding. Viruses of the yellows or clearings classes can be distinguished even in the acute phase by the ultimate expression of the fine vein banding. With the Bosumuoso 2 virus, the short lengths of fine vein banding remain brilliantly demarcated against the subsequent general yellowing; with the Surawno virus, fine vein banding is vague and diffuse but is still identifiable through the general yellowing; with the Punekrom and Aiyiboso 2 viruses the initially discrete fine vein banding becomes masked by the general yellowing.

TABLE 1.

THE MAJOR GROUPING OF WESTERN PROVINCE VIRUSES ON SYMPTOM EXPRESSION.

Symptom class.	Characteristic symptoms	Component viruses.*
Mosaic class ...	Fine vein banding, uniform close flecking and fern patterns; reminiscent of strain A.	*Amafie*, *Bosumuoso* 1, *Wiasi*, Aiyiboso 1, Nsaura, Suhuma Reserve.
Yellow mosaic class.	As in the mosaic class, but all patterns tend to be bright yellow.	*Datano.*
Yellows class...	In the acute phase leaves have a general cloudy and non-particulate yellowing; in the chronic phase various flecking patterns are produced.	*Punekrom*, *Surawno*, Aiyiboso 2.
Clearings class	In the acute phase, leaves may have a yellow pattern as in the preceding class; in the chronic phase very conspicuous transparent lesions may occur alongside the larger veins.	*Bosumuoso* 2, *Jamesi* Bakukrom.

* The viruses are named after their type locality. Those *in italics* are distinctive; the validity of those not *in italics* is still questionable. The full geographical distribution of the various viruses is not given.

A few viruses like Bosumuoso 1, Aiyiboso 1 and Nsaura appear to be almost as virulent as virus A, but most Western Province viruses are much milder and infected plants produce sequences of symptomless flushes in the chronic phase. With all but the mildest forms, however, marked defoliation is noticeable in outbreaks covering more than a quarter-acre.

All Western Province viruses in the Tafo collection have been used in protection tests against virus A and none has been found capable of inhibiting infection with the latter virus. This is especially interesting in connection with viruses of the mosaic class, whose symptoms are of a type similar to those of the virus A complex. Cross-protection tests within the Western Province complex are now being done. The Bosumtwe virus (J) has been included in these tests as its symptoms are indistinguishable from those of the Jamesi virus.

Viruses very similar in symptoms to and in some cases almost certainly identical with recognized viruses in the mosaic and yellow mosaic classes have been obtained from *Cola chlamydantha* trees, but so far viruses referable to the other two classes have not been obtained from this wild host plant.

The rate of spread of outbreaks of the Amafie and Bosumuoso 1 viruses is being studied. With the first virus, the outbreak increased from 158 to 290 trees in 1947; with the second, the amount of spread in the same period was proportionately much greater—from 29 to 128 trees.

3. *Inter-relationships of Viruses.*

An account of the different relationships of some viruses to virus A (New Juaben) on the basis of the protection test was given in the last annual report and is brought up to date below. In this work, two viruses are considered to be closely related strains if a plant infected first with one is subsequently immune to infection with the other virus.

1. *Strains conferring complete protection against virus A.*

   Attenuated virus A (Eastern Province).
   Strain H (Dawa, Eastern Province).
   Strain K (Konongo, Ashanti).

2. *Strain conferring incomplete protection against virus A.*

   Strain B (Bisa, Eastern Province).

3. *Viruses conferring no protection against virus A.*

   Virus C (Kpeve, Togoland).
   „ D (Nkawkaw, Eastern Province).
   „ E (Pamen, Eastern Province).
   „ F complex (Amafie, Bosumuoso 1, Wiasi, Aiyiboso 1, Datano, Punekrom, Surawno, Aiyiboso 2, Bosumuoso 2, Jamesi, Bukukrom, all from Western Province).
   „ G (Dochi, Eastern Province).
   „ J (Bosumtwe, Ashanti).
   „ N (Akanran, Nigeria).
   Viruses O1, O2 (Olanla, Nigeria).
   Virus O3 (Ilesha, Nigeria).

4. *Viruses conferring no protection against virus A, and forming an apparent symptom-complex with it.*

Virus M (Mampong, Eastern Province).

Viruses J and M, the only ones so far tested, are also able to build up infections in plants first infected with the attenuated strain of virus A.

It will be noticed that no virus occurring outside the Eastern Province, except that at Konongo relatively near the border, is able to immunise plants against virus A. Those Eastern Province viruses which do not protect against virus A are, except for virus D, unlike the severe virus in symptoms. Plants infected with virus E show a cloudy yellow non-particulate mottle in the acute phase, virus G does not cause swellings and virus M produces a distinctive sequence of leaf symptoms which is very unlike that of virus A. The protecting strains have chlorotic patterns fundamentally similar to those of virulent virus A but are milder. On the other hand, some of the Western Province and Nigerian viruses and the Eastern Province virus D have symptoms similar to those of virus A, yet do not afford protection.

From these results it seems fairly certain that a cacao virus with leaf symptoms differing conspicuously from those of virus A is unlikely to be able to confer protection against it (*i.e.*, to be related) though the converse is not true.

Cross-protection tests are now being done among the viruses which do not protect against virus A. Results are available for some of the Nigerian viruses. The two Olanla strains are mutually protective—one producing large swellings and cloudy yellow leaf symptoms, the other characterized by fewer and smaller swellings and conspicuous transparent lesions in the leaves. The Ilesha strain, which resembles the first Olanla strain but has a brighter chlorosis and is probably more severe, protects against either Olanla strain. Virus N, the Akanran or Egbeda virus, is not protective against the Olanla strains.

4. *Cacao Virus Symptoms.*

Virus infection in cacao develops in phases reflected by the sequence of symptom patterns in the various growth flushes produced by a plant after inoculation. The first leaf symptoms are usually conspicuous and severe; extensive chlorosis is often accompanied by crinkling and necrosis. Later patterns tend to be milder and often dissimilar from the early ones; chlorosis is limited to the sides of the larger veins and leaf size may revert to normal. With the mild viruses, this stage is succeeded by one in which symptomless flushes are produced with only occasional recurrences of patterns usually of the milder types. The phases of symptom expression have been called " acute " (initial severe) and " chronic " (milder symptoms and symptomless flushes) and it is by study of the phasic development of infection that different viruses can be distinguished. It is emphasized, however, that similarity in symptoms need not indicate

close relationship between two viruses. The symptoms of viruses A and F (Wiasi) are similar, but as the latter, milder strain cannot protect against the former, they are probably unrelated.

During the development of infection, the trend in symptom expression from comparatively severe to mild is not due to a qualitative change in the virus; this can be shown by transmissions either by grafts or insects during the various phases. The trend may be due partly, however, to reduction in virus concentration and this possibility is now being explored. Two other possibilities are either that the plant becomes adapted to the infection, or that differences in leaf symptoms and their presence or absence are the result of virus invasion of young host tissue at different critical stages of cellular differentiation. These hypotheses are now being investigated. In one experiment, groups of five saplings (2–3 years old) were decapitated at a height of 18 inches while each was in the *chronic* phase of infection with one of the following viruses: various forms of virulent or attenuated virus A, the Amafie, Bosumuoso 2, Wiasi viruses of the Western Province, viruses J, K and M. There was a recurrence of symptoms on the new growth with all the strains, and acute and chronic symptoms were repeated.

It has been noticed in other experiments, however, that decapitation does not always cause a recurrence of acute symptoms. When a long stump is left, symptoms are usually of the chronic type or are not produced. The inference is that when shoots develop from dormant buds formed before infection occurs, acute symptoms are produced; shoots developed from buds formed during the chronic phase, and so, presumably, with their tissues infected in the embryonic stage, show chronic symptoms or are symptomless. The reaction of the plant is fundamentally a passive one. The hypothesis postulating active adaptation of the plant to infection is not completely invalidated, as adaptation may be possible only by tissue in the formative stage. There is, though, no positive evidence for this. Another indication that the stage of differentiation at which virus invasion occurs is at least one important factor in symptom expression is the marked tendency for the strongest symptom expression of a flush to occur on the first-formed (lower) leaves. This is usually obvious with mild viruses where there is a recurrence of symptoms during a sequence of symptomless flushes in the chronic phase; the lower leaves, or perhaps only the lowest leaf, show symptoms while the remainder are symptomless.

More critical experiments on the mechanism of symptom expression are being done, use being made of the decapitation technique.

5. *Studies on the Virus A Complex and its Components.*

(a) *The occurrence of a complex of strains in outbreaks and in single plants.*

The variability of strain A has been recognized since the discovery, made during the search for resistant material, that some trees in

outbreaks may be infected with a milder virus than the majority. Further evidence was obtained from the work on coppicing of diseased cacao trees (see 1946/47 annual report). More recently comparative tests for differences in virulence have been made on viruses from various trees in outbreaks. The method is to infect five Amelonado cacao seedlings from each source selected and to observe the number of subsequent flushes and their symptoms. Marked variability of virus A in three separate outbreaks was thus demonstrated, the proportion of source plants from which non-virulent infection was transmitted to the seedlings being 3–5, 3–5 and 3–12. The method of choosing trees as source plants by selecting about equal numbers of " good-looking " and " bad-looking " trees known to have been infected about the same time weighted the chances in favour of finding non-virulent virus. Very mild strains of the category of " attenuated virus A " were rare; two were obtained from the first outbreak and one from each of the others. The high proportion of attenuated and semi-virulent forms in the first outbreak was not surprising as the infected trees had been coppiced some years previously and most of those surviving were infected with relatively mild virus.

The selected source plants in the last outbreak had been symptom-bearing for at least 15 months and the results showed it to be impossible to foretell accurately, even at this late stage of infection, which trees would yield non-virulent virus. Of the six trees still showing moderate vigour, little defoliation or a relative scarcity of symptoms, non-virulent virus was obtained from only two, while from the set of six badly affected trees non-virulent virus was obtained from one. After a further 15 months, all the source trees were either moribund or dead except for one of the good-looking trees; this tree had yielded non-virulent virus in the test.

The test showed that a few source plants were each infected with two viruses of striking differences in virulence. This was demonstrated for one tree in each of the second and third outbreaks and for three in the first outbreak. The first was considerably the oldest outbreak and it was probably more than a coincidence that in trees infected for the longest time there should be the greatest amount of virus variation. It was thought that a mixture of strains might be present in all the test plants inoculated from this outbreak. The plants were then coppiced at a height of 18 inches in the expectation that the symptoms of the different strains, if present, might appear on the various shoots of the new growth from each stump. This expectation was not realized; the symptoms and degree of virulence of the infecting virus as expressed prior to decapitation of each plant were reproduced on the new growth. In a few cases, the first flush from the stump consisted of both symptomless shoots and shoots with severe symptoms, but qualitatively similar virus was transmitted from each type by vectors.

These results indicate that viruses varying conspicuously in virulence may occur occasionally in the same plant, but the experiments also revealed what may be a general tendency for the virus

in the roots to be less virulent than that in the branches. In these experiments graft inoculations to a second series of five seedlings were made from lateral roots of the trees at the same time as from canopy twigs. After 15 months, the plants inoculated from the roots were never outstandingly better than their counterparts inoculated from the canopy, but those of a few series were less severely affected. The differences between the two " treatments " show up in a comparison of the numbers of flushes produced by plants of the two treatments—the fewer the flushes the greater the virulence of the virus. The data are given in Table 2. The results were analysed as for two treatments in a randomised block layout and the difference in numbers of flushes between treatments is significant at the one per cent. point.

TABLE 2.

COMPARISON OF NUMBERS OF FLUSHES PRODUCED BY PLANTS INOCULATED BY GRAFTING FROM CANOPY TWIGS AND LATERAL ROOTS OF SOURCE PLANTS.

Inoculated plants.	Source plants.																			
	A		B		C		D		E		F		G		H		I		J	
	*T	†R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R
1	4	4	4	8	2	2	4	3	2	3	5	6	6	4	3	3	5	6	2	7
2	4	5	6	7	2	3	5	5	3	3	2	7	5	6	1	2	6	6	3	5
3	6	5	6	8	3	4	6	3	4	5	5	2	4	6	2	8	4	7	3	5
4	4	5	5	6	3	4	3	3	2	7	1	4	5	7	3	3	5	5	5	6
5	5	6	6	4	3	7	5	4	1	6	3	3	5	7	1	1	6	6	3	5
Totals	23	25	27	33	13	20	23	18	12	24	16	22	25	30	10	17	26	30	16	28

* T = canopy twig source.
† R = lateral root source.

In further work on this question four trees in one outbreak were used as source plants and comparisons made between four groups of five plants infected from each tree; budwood was selected from four sites, one to each group—lateral roots, canopy twigs, main fan branches and basal suckers. Readings were made on the numbers of flushes, numbers of leaves and total leaf areas produced by the seedlings during a period of 18 months following inoculation. In none of the four trees was the virus from the roots shown to be significantly milder than that obtained from one or other of the aerial sites. The observations indicated, however, that there appeared to be a greater chance of obtaining the mildest virus of the complex infecting the plants from the roots than from any other part. As evidence for this, there are provided in Table 3 the aggregate numbers of flushes produced by the plants of the sixteen different series.

TABLE 3.

TOTAL NUMBERS OF FLUSHES PRODUCED BY SERIES OF 5 SEEDLINGS INFECTED FROM VARIOUS SITES ON 4 TREES.

Source plant.	Site.			
	Canopy Twig.	Main Fan.	Basal Sucker.	Lateral Root.
A ...	39	38	47	42
B ...	36	45	39	45
C ...	38	10	25	39
D ...	26	19	14	25
Totals...	139	112	125	151

To summarize, it is evident that virus A exists as a complex of strains. In outbreaks of 50 trees or more, extensive variability seems to be the rule, but seldom does a tree become infected either completely or dominantly with attenuated strain A and so survive. In most trees, one strain of the complex appears to be either the sole or dominant virus, though there may be a tendency for a slightly milder strain of the complex to occur in the roots. Further work is being done on the distribution of strains in the plant as hitherto only small portions of source plants have been explored either by the taking of budwood or feeding vectors; stress is being laid on the possible concentration of the mildest parts of the complex in the roots.

(b) *The comparative transmissibility of attenuated and virulent strains of virus A.*

The most noticeable difference between virulent and attenuated strains of virus A is that whereas in the former symptoms occur on almost all flushes, in the latter conspicuous mosaic, if ever produced, is confined to the first flush following the incubation period and to very occasional subsequent flushes. It has been considered that the absence of symptoms in the chronic phase may be due to a virus concentration far below that in plants infected with the virulent strain. Nevertheless, a certain critical concentration must be maintained to account for the almost invariable immunity of attenuated A-infected plants to virulent virus A.

Direct comparative tests for virus concentration like the local lesion test are not possible with cacao viruses as, so far, mechanical sap transmission has not been achieved. The most applicable indirect method giving quantitative results is a comparison of transmission

rates of two strains by an insect vector under controlled conditions. The transmissibility of attenuated A has a practical as well as academic significance since this virus is the basis of a type of resistance to virulent A. Comparative tests between the virulent and attenuated A are now being carried out using source plants which were infected as beans. Insects taken from a single colony are allowed to feed on the seedlings until they produce nymphs which are later transferred to test beans; the transference rate of insects to beans was 30 crawlers or nymphs for tests 1 and 3 and in the remainder ten per bean. The transmission rates in the last column of Table 4 indicate the total number of beans used for the relevant part of the test and the number which developed into infected seedlings.

TABLE 4.

COMPARATIVE TRANSMISSIBILITY OF ATTENUATED AND VIRULENT STRAINS OF VIRUS A FROM SELECTED FLUSHES OF INFECTED SEEDLINGS.

Test.	Vector.	Virus.	Source plant.	Vector feeding site on source plant.		Transmission rate.
				Flush.	Symptoms.	
1	F. virgata	Att.	32/22	4th	—	0–15
		Vir.	32/9	4th	+	0– 9
2	F. virgata	Att.	32/22	5th	—	0–27
				4th	—	0–30
				3rd	—	0–30
				2nd	—	4–30
				1st	+	0–29
		Vir.	32/9	4th	+	0–30
				3rd	+	0–30
				2nd	+	10–30
				1st	+	7–30
3	Ps.njalensis	Att.	32/25	4th	—	3–12
		Vir.	32/8	4th	+	4– 4
4	Ps.njalensis	Att.	35/118	1st	+	23–25
		Vir.	38/11	1st	+	5– 6
		Vir.	38/15	1st	+	30–33
5	Ps.njalensis	Att.	34/377	1st	+	25–28
		Vir.	34/389	1st	+	6–11
		Vir.	34/381	1st	+	32–34
6	Ps.njalensis	Att.	32/5	6th	+	37–44
		Att.	32/25	5th	—	1–11
		Vir.	32/7	5th	+	18–32
		Vir.	32/13	5th	+	18–28

From these results it would seem that, during the acute phase or at a recurrence of symptoms, attenuated A is as readily transmissible as the virulent strain at least with the insect rates used. In test 6, transmission rate is proportionately higher from one of the attenuated A plants than from the virulent A plants, perhaps because the feeding site in the former plant was a hardening flush, in the others fully mature tissue. There is apparently a greater reduction in available virus in the attenuated A plants as they enter the chronic phase and become symptomless. A more definite statement must await the results of replicated tests and variable vector rates using pairs of plants with parallel development of the two strains.

6. *Virus Resistance.*

Experiments on the resistance of selected clones to virus infected by grafting have not revealed any immunity. The discovery of comparatively tolerant clones and of clones with resistance acquired by prior infection with an almost symptomless virus was reported in the 1946-7 annual report and further experiments have supported the conclusions then drawn.

Experiments are now in progress to test the resistance of numerous clones and seedlings of new introductions to infection by vectors.

7. *Effect of Viruses on the Roots.*

It was observed that infected cacao seedlings had a reduced root system, owing to rootlet necrosis and suppression of new root development. An investigation was then carried out to determine the extent of this effect on the roots and whether it precedes that on the leaves and stem of the plant.

Weighed cacao beans were infected by insect vectors and the developing infected seedlings and healthy controls were harvested after four and six weeks. The leaves, stem, tap-root and feeding roots of each plant were dried and weighed separately. The water content and the dry weight of all parts of the plants infected with virus A were less than those of healthy plants. There is an indication, now being tested by further analysis, that the weight of fine roots is proportionately less in plants six weeks after infection, but it is not yet ascertained whether the virus affects the roots before or after the effect on the leaves.

8. *Mechanical Transmission.*

Another attempt at mechanical transmission of cacao virus has been made without positive result. In previous trials, sap had been extracted from the leaves and stems, but with great difficulty owing to the presence of mucilage. It has been thought that perhaps one reason for failure to transmit the cacao viruses mechanically lies in absorption of virus by mucilage. In view of the absence of mucilage canals in the cotyledons, the use of the juice from this source would indicate whether such absorption was a factor in previous failures to obtain sap transmission.

Cotyledons were taken from infected seedlings at a stage just prior to full hardening of the first leaves. Previous work had shown that virus is readily obtainable from cotyledons of this age by insect transmission—the rate being comparable with that obtained from the first leaves. A small but adequate quantity of juice is expressible from the ground pulp of a dozen cotyledons. The test plants were cacao beans and inoculation of the fluids carried out in each case by needle puncture of the radicle and main cotyledonary nerves, abrasion of the radicle, and painting of the radicle and inner surface of the cotyledon with a fine camel-hair brush; surplus fluid was removed after a short time by washing the beans in tap water and planting followed immediately.

In experiments with virus A, 57 beans were inoculated with fresh crude sap, 41 with sap clarified by centrifuging at 3,000 r.p.m. and ten from each of the following :—the supernatant fluid obtained after ammonium sulphate treatment of clarified sap, the first and second supernatants after washing the precipitate from ammonium sulphate treatment with small quantities of distilled water and the precipitate itself, shaken in a small quantity of distilled water.

In an experiment with virus M, ten beans were inoculated from each of six fluids prepared as above. No transmissions have yet been obtained in any of the seedlings grown from the beans.

9. *Rate of Spread and Effect on Yield.*

Unrestricted natural spread of swollen shoot (virus A) in the demonstration area of 8¼ acres has been recorded for two and a half years. In August, 1945, when readings were commenced, just under a third of the trees were diseased, in August, 1946, just under a half and in August, 1947, just under two-thirds. By March, 1948, 75 per cent. of the trees in the area were diseased.

TABLE 5.

INFECTED AND MORIBUND OR DEAD TREES IN 8¼ ACRES AT THREE ANNUAL STAGES.

	Original total of mature trees (healthy and diseased).	August, 1945.		August, 1946.		August, 1947.	
		Infected.	M or D.*	Infected.	M or D.*	Infected.	M or D.*
Number...	4,636	1,450	361	2,134	671	2,967	1,457
Percentage	—	31	8	46	14	64	31

* Moribund or dead trees, included in number of infected trees.

The yield of the area has fallen markedly in the three seasons. Figures are given in Table 6.

TABLE 6.

YIELD OF CACAO FROM THE RATE OF DESTRUCTION AREA FROM 1945 TO 1947.

Year.	Number of Pods harvested.
1945	41,771
1946	33,716
1947	24,569

THE FACTORS IN INSECT TRANSMISSION OF VIRUSES.

During the year the variability in the results of vector experiments has been much reduced so that insects can now be manipulated to give any desired degree of infection with the principal viruses and when anomalies occur a quantitative estimate of the probability of their being due to chance can be made.

The virus sources have been standardised and for most of the work infected seedlings of not more than 40 days old are used as source plants. *Pseudococcus njalensis,* Laing, " crawlers " (1st and 2nd instar larvae) are used as the standard vectors. Large populations of these crawlers can be obtained by colonising young plants between 20 and 30 days old with gravid females of *Ps. njalensis* from the field; colonies of young insects are fit for use about seven days after the original colonisation.

1. *The Effect of Insect number on Transmission Rate.*

The effect of insect number has been investigated for its practical applications and for the theoretical interest of discovering if there is any " mass action " effect in mealybug transmission of the virus, i.e., whether the effect of a large number of insects infecting a plant is greater than the sum of the effects of individual insects. The table given below shows for virus A and *Ps. njalensis* the totals of infections caused by varying numbers of insects in an experiment replicated six times. In the same table can be seen the expected numbers calculated from the probability of infection by one insect. The figures in both columns agree very closely and the " goodness of fit " has a probability of 0·9—0·95 in the table of chi squared. There is thus no mass action effect.

TABLE 7.

Number of insects.	Number of infections out of 60		Chi squared.
	Observed.	Calculated.	
1	6	6·18	0·0052
5	32	25·15	1·8657
10	42	39·77	0·1250
15	48	48·25	0·0013
20	54	53·18	0·0126
25	57	56·04	0·0164
30	57	57·70	0·0081

Chi squared total = 2·0343

The probability of successful infection by one insect is ·103 and using 30 insects the expected probability of success is ·9617.

2. *The Effect of Age of Test Plant on Infection Rate.*

For practical reasons it is not always possible to use embryos as test plants. Discrepancies between the expected rates of infection and the actual rates when seedlings were used as test plants led to an investigation of the effect of age of plant. Plants of ages from 0 to 6 weeks were colonised in a randomised fashion each with 30 crawlers of *Ps. njalensis* carrying virus A. The treatments and the total number of infections out of 48 trials (six blocks of eight plants per treatment) are listed in Table 8.

TABLE 8.

Age.	Appearance when inoculated.	Total No. infections (out of 48).
0 weeks ...	Fresh beans laid on soil	36
2 weeks ...	Cotyledon emergent	39
3 weeks ...	Cotyledon and young plumule ...	40
4 weeks ...	Leaves expanding	25
5 weeks ...	Leaves maturing	20
6 weeks ...	Leaves mature	22

In the statistical analysis the results fall into two groups; plants up to three weeks of age show a significantly higher rate of infection than those of four to six weeks. The difference between totals required for significance is 9·529.

It has been found in routine experiments using mature plants and cuttings that about 50 per cent. infection is obtained using 30 crawlers per plant and this figure agrees with that for four to six weeks old plants in the experiment above. It is not possible to say yet whether the differences are real differences in the susceptibility of the tissue of young plants (mostly cotyledon) or whether the differences are related to mechanical difficulties of mealybug feeding in the older plants, but with most plant viruses the susceptibility of the plant decreases with age.

When suspected alternative hosts are being infected as beans or dissected embryos, it is sometimes difficult to remove one cotyledon as is done in the cacao controls, or the removal of one cotyledon may seriously hinder the growth of the plant (e.g., *Cola chlamydantha,* K. Schum). The comparison of dissected and undissected beans makes a considerable difference in the infection rates. When whole beans of *Theobroma bicolor,* Humb. et Bonp., are compared with whole beans of *T. cacao* there is no statistical difference between the infection rates but if whole beans of *T. bicolor* are compared with dissected beans of *T. cacao,* the *T. cacao* gives a significantly higher rate of infection ($P = ·05$) than the *T. bicolor* (Table 9). This effect is a purely mechanical one, the insects can find feeding sites more readily on the split beans.

TABLE 9.

NUMBER OF INSECT TRANSMISSIONS OUT OF TEN BEANS.

T. bicolor unsplit.	*T. cacao* unsplit.	*T. bicolor* split.	*T. cacuo* split.
5	4	5	8
1	2	1	3
2	2	7	7
8	2	2	8
5	4	4	9
21	14	19	35

3. *Biological Races of Mealybugs.*

It was at one time suspected that some of the discrepancies and failures in transmission might be due to the occurrence of non-transmitting biological races of *Ps. njalensis.* Accordingly nine colonies were established from single gravid females, from widely separate areas of the environs of Tafo, and their ability to transmit virus M was tested for three generations. All transmitted the virus at approximately the same rates. It seems from these observations and from the uniformity of routine results now obtained in the laboratory where many hundreds of sources of *Ps. njalensis* have been used in experiments with consistent transmission rates, that the occurrence of non-transmitting races of *Ps. njalensis* (for virus M), if they occur, is not of such frequency as to vitiate the reliability of transmission studies. No such detailed studies of virus A and *Ps. njalensis* have been made but routine transmissions do not suggest the presence of biological races of different transmitting powers. *Pseudococcus citri* Risso is easier to breed from single insects, and nine separate collections from Tafo and one pooled collection from Kpeve have been tested thoroughly for their ability to transmit viruses A, M and C. All have transmitted viruses A, C and M except Source I 47/78 which has consistently failed to transmit Virus C. In a series of replicated experiments control *Ps. citri* insects transmitted virus C 17 out of 55 times (with five insects per plant) while Source I 41/78 failed to give a single transmission. Specimens of this race have been carefully examined and it falls well within the normal range of variation of *Ps. citri* in West Africa.

4. *How the Insect Picks Up the Virus.*

(a) *Starved insects.*

When crawlers of *Ps. njalensis* which have been previously starved for 12 hours are placed on the leaves of infected plants they do not feed immediately. The number of insects feeding increases linearly during the first six hours and then remains constant. The number of infections obtained from insects feeding on these leaves at first

increases in a similar manner but instead of becoming steady at six hours continues to rise until it reaches a maximum between eight and ten hours. A sharp fall takes place at 12 hours. The data on which this statement is based were obtained in a series of six replicated experiments in which starved *Ps. njalensis* crawlers were fed on young leaves of month old plants infected with the Mampong virus, for periods up to 12 hours at two hour intervals.

(b) *Unstarved insects.*

In a parallel series of experiments with unstarved crawlers of *Ps. njalensis* the number of insects feeding again rose approximately linearly between 0 and 6 hours but the gradient of the plotted line was less steep. A similar flattening out between 6 and 12 hours was apparent but the numbers of feeding insects were consistently less than with the starved insects. The numbers of infections increased linearly from 0 to 12 hours but did not reach such a high maximum as with the starved insects at 8 and 10 hours. There was no sign of the sudden drop at 12 hours exhibited by the infection rate of the starved insects.

5. *How the Insect Infects the Plant.*

Most of the insects which carry plant viruses have relatively short stylets and the penetration time taken to reach the feeding site is short, of the order of a few minutes. The time taken to infect the host is also short, although the amount of infection increases appreciably when the insects are left on the healthy plant for periods of hours. Not much more is known of the feeding habits of the *Coccoidea* than that the long slender stylets penetrate deeply into the plant. It was thus of interest to examine the feeding behaviour of these insects in some detail.

Serial sections were cut in order to determine the feeding sites of insects feeding on young cacao leaves. The stylets and stylet tracks (which show up well when stained with Safranin) take an intracellular course through the cells of the cortex; the tracks often branch in the stele and the tortuous course of single tracks makes the definition of their endpoint extremely difficult. Many of these tracks pass through the phloem and appear to end in the xylem and others pass through the xylem to the phloem. Other tracks do not reach either tissue, but these may be trial penetrations without feeding by the insect.

The feeding mechanism has been studied in more detail by allowing the insects to feed on blocks of 3% cleared agar, a method suggested by the work of Dr. Walter Carter. Rings of solid agar were cut from poured Petri plates and removed to a glass slide, a number of adults or nymphs of *Ps. njalensis* were then placed in the centre of the ring of agar and a cover glass placed on top. After 30 minutes in the dark the slides were examined under the microscope. When an insect was settling to feed the following series of events took place. The rostrum, which lies about the centre of the ventral surface, makes

tentative thrusts at the agar and finally becomes present against its surface. When the tip of the stylets enters the agar, the rostrum retracts and advances with a rapid, pulsating motion and the stylets penetrate at what appears under low power magnification to be a steady rate. Under a higher magnification the tip of the stylets can be seen to move with short discrete movements, each preceded by the secretion of a droplet of saliva from near the tip of the stylets; these retract a little before moving through the salivary droplet and moulding a tube actually composed of a series of droplets with a straight tube through the centre, and having a laddered appearance under low magnification. There is no difference between adults and nymphs in the rate of penetration (about 0·5 mm. per second) but the differences in stylet length are such that the crawlers penetrate to their greatest extent in about 15 minutes while adults may take up to 30 minutes after settling. The stylets do not always continue to move inwards but may stop or they may be partially withdrawn and branch off again at another angle. In sections of leaves and on agar many short terminal branches may arise from one main stylet track.

This feeding behaviour is reflected in the results of experiments on the effect of length of time of test feeding. When this was determined for virus M for periods of 1, 2, 4 and 12 hours in a series of six replicated experiments, there was found to be no significant increase in numbers of infections after one hour. The increase in infection rate for periods within an hour are shown in the following table.

TABLE 10.

Test feeding time minutes.	Mean No. infections out of ten.
10	0
20	1·5
30	4·0
40	5·3
50	6·2
60	5·9

The data are best fitted by a linear regression line of formula $y = -0{\cdot}645 + 0{\cdot}127X$.

6. *The Loss of Virus by Starved Insects.*

When transferring vectors from source plants to test plants there is a choice between insects actually feeding and insects which have fed and are walking about. It has been found that mealybugs nymphs are dispersed by wind. From both these considerations it is important to know if there is any falling off in infective powers of insects after short periods of starvation and how long they remain infective during prolonged starvation. Many experiments on starvation of crawlers

of *Ps. njalensis* up to 12 hours have shown no falling off in the infective ability of insects carrying the virus M; several longer experiments up to 74 hours have shown that infection does not persist after a period of 36 hours (the crawlers will generally remain alive and active up to about 40 hours but under exceptionally favourable conditions they may remain active longer). Similar results have been obtained with young adults in less extensive tests, and also with *Ps. citri* and virus A.

Mealybug Species and Cacao Viruses.

Six species of mealybugs are being tested as vectors with each of 20 cacao viruses. These experiments have discovered two new vectors, *Pseudococcus bukobensis,* Laing and *Ps. longispinus,* T—T. The transmissibility of the different viruses by the different vector species may help to sort out the relationships of the viruses to each other. The most interesting points in the results obtained so far are :—

(i) No vector has been found for the Asalu (Nigeria) virus. With the exception of this virus;

(ii) *Ps. njalensis, Ps. citri* and *Ps, bukobensis* have transmitted all the viruses with which they have been tested.

(iii) *Ps. longispinus* has transmitted viruses C (Kpeve) and M (Mampong) but not A (New Juaben) nor the Ivory Coast and Nigerian viruses, whereas

(iv) *Ferrisia virgata,* Ckll, has given the reverse result; it has transmitted all the viruses except C and M.

Alternative Host Plants of Cacao Viruses.

1. *Cola chlamydantha* K. Schum. (Sterculiaceae). This is a small understorey tree in the forest of parts of the Western Province of the Gold Coast, not extending to the Eastern Province or Ashanti. It is usually unbranched, reaching a height of 40 feet with a crown of large palmate leaves on long petioles. The leaves are very leathery and long-lived.

Leaf symptoms found on a coppiced plant of this species growing in a swollen shoot outbreak near Wiawso led to the discovery of the first indigenous host of a cacao virus. Since this discovery in December, 1946, the distribution of the species and its importance as an alternative host has been investigated. In a survey made in May, 1947, the prevalence of infected trees (*C. chlamydantha*) in bush and cacao farms in the Wiawso district was satisfactorily demonstrated; 10 out of a sample of 25 *C. chlamydantha* plants were shown to be infected, by virus transmission to cacao by mealybugs. Seven plants chosen from the north-western fringe of the Suhuma Forest Reserve, some distance from cacao farms, were tested in the same way and three were found to be infected.

The presence of virus in *C. chlamydantha* away from cacao was of great interest and a further search for infection in forest-growing specimens was made in August. This time two areas were selected.

The first was a patch of secondary forest to the north of the village of Nyamebekyire, near Wiawso, fully a mile in direct line from the nearest known outbreak of swollen shoot. The second area was along the path from Adiembra to Kobo which for almost its entire length traverses the north-western fringe of the Suhuma Forest Reserve. The choice of specimens was arbitrary except that there was a tendency to test those showing an abnormal or diseased appearance. Mealybugs (usually *Ps. njalensis*) were present among the bracts of the stem tips of most trees and were used for the infestation of cacao beans at rates of ten adults or thirty nymphs per bean. When there was no natural infestation of mealybugs, virus-free insects were applied to detached stems or leaves in cigarette tins or test tubes, and transferred to cacao beans about 24 hours later.

Twenty plants were tested from the Nyamebekyire area and seven found to be infected; five showed symptoms and two were symptomless. 60 plants from the Suhuma Reserve were tested and 25 shown to be infected; ten were plants with leaf symptoms only, six without leaf symptoms but with scaly or gnarled stems, close bract formation or dieback, four with both leaf symptoms and stem abnormalities and the remaining five were quite normal in appearance. Most infected plants were trees up to 40 feet tall and about 22 inches in girth at ground level, but a few were coppiced plants or saplings.

As this non-intensive method showed that over one-third of the trees tested were virus-infected, there is probably a very high rate of infection in the species in the two areas; this must mean a long infection period in the populations. The canopies of neighbouring *C. chlamydantha* trees are rarely in contact as happens with cacao, and consequently the tree-to-tree spread would be expected to be slow. In the Suhuma Reserve there are scattered cacao farms some with swollen shoot and from which, it might be argued, infection reached *C. chlamydantha*. From the work done so far, however, it is reasonable to contend that cacao became infected from the *C. chlamydantha* in these districts and to confirm this, *C. chlamydantha* trees will be tested for virus infection in distant reserves near which cacao farms are rare.

A variety of virus strains has been obtained from cacao in the Western Province but so far, only viruses of the mosaic and yellow mosaic classes have been found in *C. chlamydantha*. Viruses causing a variety of symptoms when transferred to cacao, occurred in the *C. chlamydantha* populations of the Suhuma and Nyamebekyire areas; the viruses often differed greatly in virulence from tree to tree but were all referable to either of the two classes of symptoms in cacao. The ability of *C. chlamydantha* seedlings, and also those of *C. cordifolia* R. Br. and *Ceiba pentandra* Gaertn., to become infected with Western Province viruses of all four classes is being tested in the laboratory.

Symptoms in C. chlamydantha. It is not yet known to what extent the various stem abnormalities on diseased plants are the result of virus infection. Many of the vague leaf chloroses like blotchy vein

banding are true symptoms as they can be reproduced by artificial infection of seedlings. Leaf symptoms are frequently evanescent, disappearing as the leaf matures, and this may account for the occurrence of symptomless infected plants in the field.

C. chlamydantha does not occur in the Gold Coast outside the Western Province and so cannot be incriminated as the wild host of the numerous other cacao viruses. For these, various common forest species in the Sterculiaceae and related families are being tested. In these experiments, seeds or seedlings of the species concerned are infested with virus-carrying mealybugs and, after sufficient time has elapsed for an incubation period, back transferences are made to cacao whether symptoms appear on the seedlings or not. So far, no alternative hosts have been discovered naturally infected in the Eastern Province or Ashanti but seedlings of a number of species have been infected in the laboratory.

2. *Cola cordifolia R. Br.* (*Sterculiaceae*).

Plants have been infected in the bean and young seedling stage with virus A from cacao; vectors were *Ps. njalensis* and *Ps. citri* for the seedling and bean transmissions respectively. Symptoms were essentially similar to those on cacao—general chlorotic flecking or a banding of the larger veins—but were confined to one or two leaves and after these were shed the plants remained symptomless.

C. cordifolia has also been infected with virus C and with the Wiasi virus (F) of the Western Province using *Ps. njalensis* as a vector. No symptoms developed with virus C, but virus F caused symptoms similar to those produced by virus A.

The Offa Igbo (Nigeria) virus has been transmitted to and from *C. cordifolia* in experiments now in progress.

3. *Cola nitida A. Chev.* (*Sterculiaceae*).

Many attempts to infect this species with cacao viruses have failed as judged by back transmission to cacao; a number of experiments are still in progress.

4. *Cola togoensis Engl. et Krause* (*Sterculiaceae*).

No cacao virus has been transmitted from seedlings of this species in our experiments. A *C. togoensis* tree was discovered in Nigeria naturally infected with a vein-clearing virus which has been transmitted by grafting but not yet by vectors.

5. *Sterculia rhinopetala K. Schum.* (*Sterculiaceae*).

Members of this species have been infected with virus C. The insects were fed on young seedlings before the leaves had expanded and the first true leaves showed pale green circular spots, up to one centimetre in diameter, on either side of the midrib and some of the main veins. These spots were caused by the clearing of the microscopic veins. The next leaf showed a large area of clearing on one side of the lamina and sometimes yellow banding of the other main veins.

The cleared area did not grow and the leaf assumed a sickle shape and crumpled appearance. The subsequent leaves have shown no symptoms. Eight out of 26 plants have shown symptoms where four cacao seedlings out of eight became infected. Back transmission to cacao from symptom-bearing *S. rhinopetala* was successful.

Sterculia rhinopetala has also been infected by virus M. Five out of 20 *S. rhinopetala* plants became infected with virus M (the viruliferous insects were fed on the embryo); the cacao controls gave 10 infections out of 10. The symptoms showed in the first true leaves as a dark banding of the secondary and tertiary veins of the young leaf, reminiscent of the red vein symptom in cacao. This gave place to a bright yellow vein banding as the leaf matured. In one plant this symptom appeared in the second true leaf. The subsequent flushes in all have been symptomless. The symptom bearing Sterculia plants have all given back transmissions to cacao.

Attempts to infect *S. rhinopetala* with virus A have failed so far.

6. *Sterculia tragacantha Lindl* (*Sterculiaceae*).

Members of this species can become infected with virus M. Twenty-four seedlings of *S. tragacantha* were colonised with *Ps. njalensis* carrying virus M; 22 out of 24 controls became infected. No symptoms have shown on the *S. tragacantha* plants but virus M has transmitted to cacao five times in a total of 116 back tests, twice from one plant. Four symptomless plants of *S. tragacantha* thus were carrying the virus when tested 42 and 55 days after infection but all subsequent attempts to recover the virus have failed.

Many attempts to infect *S. tragacantha* with viruses A and C have failed.

7. *Adansonia digitata Linn.* (*Bombacaceae*).

Seedlings of the Baobab tree are as susceptible as cacao to viruses A and C, and show similar though less prominent symptoms. The viruses have been transmitted back to cacao from *Adansonia* seedlings as readily as from cacao to cacao.

8. *Ceiba pentandra Gaertn.* (*Bombacaceae*).

Seedlings of six months and two years old were infected with Virus A by transferring mealybugs (*Ps. njalensis*) from infected cacao. Leaf symptoms were similar to those on cacao and the symptom phase lasted over several leaves, but infected plants eventually became symptomless and there was not much apparent loss of vigour. The species seem somewhat resistant to virus A; back transmissions to cacao have occurred from only six out of 20 plants given thorough infestations with virus-carrying mealybugs.

Ceiba appears to be more susceptible to the Offa Igbo (Nigeria) virus, however, with which experiments are still in progress.

9. *Bombax buonopozense P. Beauv.* (*Bombacaceae*).

Seedlings of six months and about two years old were infested with virus A—carrying *Ps. njalensis* from cacao. Subsequent leaf symptoms were of doubtful significance. Like *Ceiba*, this species seems quite resistant; back transmissions have occurred from only three of 20 plants given thorough infestations, and in one case only was transmission rate high.

Attempts to infect seedlings of *Triplochiton scleroxylon* K. Schum. a dominant forest tree and common member of the Sterculiaceae have so far failed; a similar negative result was obtained with a common natural host plant of *Ps. njalensis* the myrmecophyte *Canthium glabriflorum* Hiern (Rubiaceae).

The Biology and Bionomics of Mealybugs.

1. *The Population Experiment.*

The one-acre plots, selected at random from the cacao growing on the New Acquisition, have been visited at monthly intervals since May, 1947, and 12 cacao trees, selected at random from those growing on the plot, felled. All mealybugs on the felled trees were counted according to feeding site, specimens of attendant ants collected, and the adult mealybugs brought to the laboratory for parasitic breeding.

The results given below are all referable to the first nine monthly visits to the ten plots, and are thus obtained from a total of 1,080 cacao trees felled and examined—that is 108 trees from each plot. Table 11 gives the numbers of trees infested with mealybugs over the sampling period in question.

(*a*) *General results.*

TABLE 11.

INFESTATION OF CACAO AT TAFO WITH MEALYBUGS.

(*Number of Trees infested out of a possible total of* 1,080).

	Known Virus Vectors.					Other *Ps. spp.*	
	Ps. njalensis.	*Ps. citri.*	*Ps. bukobensis.*	*Ps. longis-pinus.*	*Ferrisia virgata.*	*Ps. concavo-cerarii.*	*Ps. spp.*
Trees infested	384	122	16	3	6	10	3

In a number of cases more than one mealybug species was found on one tree; in fact, 456 of the 1,080 felled trees were infested with one or more mealybug species, and 452 of these were infested with one or other of the species known to be swollen shoot vectors. It is thus safe to say that over 40% of the cacao in the Tafo region is infested

with vectors. The actual numbers of each species of mealybug encountered are given in Table 12.

TABLE 12.

NUMBERS OF MEALYBUGS TAKEN FROM THE 456 INFESTED CACAO TREES.

Mealybug species.	
Ps. njalensis	80,109
Ps. citri	660
Ps. bukobensis	60
Ps. longispinus	4
Ferrisia virgata	7
TOTAL vectors	80,840
Ps. concavocerarii	26
Other *Ps. spp*	3
TOTAL mealybugs ...	80,869

Ps. njalensis is thus the most common vector in the Tafo district and the next common is *Ps. citri*. In view of the relatively insignificant importance of *Ps. citri* and the other vector species in relation to the infestation rate of *Ps. njalensis* the majority of the results detailed below are referable to *Ps. njalensis* only.

(*b*) *Distribution of Ps. njalensis on the cacao tree.*

The feeding sites for all mealybugs were recorded, and the 80,109 *Ps. njalensis* collected were shown to have the following distribution :—

Canopy.			*Trunk.*			*Chupons.*		
		%			%			%
Shoots	56,248	70	Pods	9,871	12	Stem	1,672	3
Bark	7,262	9	Bark	1,261	1			
Pods	2,970	4						
Leaves	825	1						

As such, 84% of the *Ps. njalensis* collected were taken in the canopy layer at a height of 15-25 feet above ground level. A similar distribution was found with *Ps. citri*, 78·3% being taken in the canopy. The 80,109 *Ps. njalensis* were collected from a total of 10,475 " colonies " (i.e., aggregations of adults, nymphs and crawlers) and of these colonies, 74·6% were protected by carton ant tents. The balance of 2,660 colonies were either in cracks in the bark, old capsid lesions, or as discrete colonies on pod or flower stalks or on leaf petioles. It is thus clear that three-fourths of the *Ps. njalensis* colonies in the field at Tafo are being actively attended by ants.

(*c*) *Ant-mealybug associations.*

A variety of complex relationships appears to exist between the cacao-feeding coccids—in particular *Ps. njalensis*—and a number of species of ants commonly found associated with them. For example the red tree ant, *Oecophylla longinoda*, Latr., is found almost invariably associated with the brown cacao scale *Stictococcus sjostedti*, Ckll., but only very occasionally does it pay any attention to true mealybugs of the Pseudococcid series. A black *Camponotus sp.* (*F* 120 in the W.A.C.R.I. ant collection) is a frequent aphid tender, attends mealybugs sporadically, but rarely attempts to associate itself with Stictococcids. Similarly, ants of the sub-family Myrmicinae may be obligatory coccidophiles, sporadic coccidophiles, directly predaceous on coccids, or may ignore the coccids throughout their life cycles. A total of 62 ant species has so far been taken from the 1,080 cacao trees felled in the populations experiment, and from the mealybug colonies collected from pods during the harvesting season. Of these, 42 are referable to the Myrmicinae (Crematogasterini: 17 species; Pheidolini: 11 species; Tetramoriini: 2 species; other tribes: 12 species); 13 to the Formicinae; five to the Dolichoderinae, and one each to the Ponerinae and Pseudomyrminae. Work is still in progress to determine which of this assemblage of species are beneficial to pseudococcids and which are predaceous on them, but it can be safely stated at present that the Crematogasterini are very largely beneficial, the Pheidolini partly predaceous, and the Formicinae, Dolichoderinae, Ponerinae and Pseudomyrminae are largely predaceous. Table 13 gives a summary of the ant relationships on the 1,080 trees felled to date.

TABLE 13.

ANT COLLECTIONS FROM 1,080 FELLED TREES.

Sub-family or Tribe of ants.	
Crematogasterini	370
Pheidolini	51
Other Myrmicinae ...	140
Dolichoderinae	2
Formicinae	513
Pseudomyrminae	1
Ponerinae	1
Totals	1,078

Unlike the mealybug infestation rate, the degree of ant infestation was relatively constant from plot to plot, though there was considerable variation in the species making up the plot totals. Table 14 shows the 561 ant collections referable to the Myrmicinae split up into genera and species and tabulated in relation to their individual association with *Ps. njalensis*.

TABLE 14.

INTER-RELATIONSHIP OF CERTAIN ANT SPECIES WITH *PS. NJALENSIS.*

	Times species taken out of 1,080 possible occasions.	Times species taken in association with *Ps. njalensis.*	% association with *Ps. njalensis.*
Crematogaster striatula	162	154	95
Cr. luctans	22	21	95
Cr. " 361 "	43	40	93
Cr. " 257 "	74	60	81
Cr. africana	15	8	53
Cr. 141 (*a*)	39	7	18
Other Cr. species	15	9	60
Pheidole megacephala	46	26	57
Other Ph. species	5	3	60
Other Myrmicinae	140	30	21
Totals	561	358	64

These results indicate clearly that a small group of species within the Crematogasterini are probably obligatory coccidophiles, and as such are of considerable importance with regard to the survival of *Ps. njalensis* under field conditions. This point is further elucidated by Table 15, in which " tented " and " untented " *Ps. njalensis* collections have been tabulated in relation to the ants present on the trees at the time of felling.

TABLE 15.

ATTENDANCE BY ANTS ON *PS. NJALENSIS.*

Total trees with *Ps. njalensis.*	Trees with carton ant tents			Trees without carton ant tents		
	and with mealybug-tending ants.	and with non-mealybug-tending ants only.	without any ants.	and with mealybug-tenders.	and with non-mealybug-tenders only.	without any ants.
384	311	14	11	9	27	12

It will be noted that mealybug-tending ants were present on 320 trees, though the fact that tented mealybug colonies were present on a further 25 trees indicates that there were true attendant ant species associated with these trees but that they were probably all in their main nest on a neighbouring tree at the time of felling. It is therefore safe to say that attendant ant species were present in association with *Ps. njalensis* on 89% of occasions, and that ant species not normally

attendant on this mealybug were present to the extent of an additional 7%. In other words, only on 4% of the times when it was collected was *Ps. njalensis* completely unattended by ants. From the 12 trees unattended by ants a total of 216 *Ps. njalensis* were collected, 136 from one tree, 68 from three other trees, and the balance of 12 from the remaining eight trees. It is thus safe to state that only in rare instances does *Ps. njalensis* succeed in establishing itself satisfactorily in the field free from attention by ants.

(*d*) *Harvesting of the ten plots.*

In order to obtain some idea of the status of the ten plots with regard to yield of cacao, each plot was harvested individually six times. Harvesting was started in September and continued at monthly intervals until the end of February. Mealybug-infested pods were noted, as well as ant attendants, and a proportion of the adult mealybugs was brought back to the laboratory for parasite breeding. Table 16 gives the total pods harvested from each plot and the numbers infested by various species of coccids; Table 17 gives the bulked results for all harvests on all of the plots with regard to the mealybugs and ants present.

TABLE 16.

PLOT HARVESTING.

Plot.	1	2	3	4	5	6	7	8	9	10	Totals.
Total Pods harvested ...	2,456	2,328	3,181	4,191	5,467	1,146	1,714	802	1,068	3,359	25,712
Pods with *Ps. njalensis* ...	522	82	25	74	281	44	126	15	145	228	1,542
Pods with *Ps. citri*	8	18	10	37	14	6	16	—	7	19	135
Pods with Other *Ps. spp.* ...	—	2	—	3	7	—	1	—	3	2	18
Pods with *Sticto-coccus sjostedti*	70	102	23	163	67	126	178	53	62	113	957

TABLE 17.

MEALYBUGS AND ANTS ON INFESTED PODS.

Mealybug species.	Infested pods harvested.	Number of mealybugs thereon.	Number of infested pods attended by ants.	Infested pods without ants.
Ps. njalensis	1,542	84,483	1,295	247
Ps. citri	135	798	64	71
Ps. concavocerarii	15	27	2	13
Ps. bukobensis	2	3	1	1
Paraputo ritchiei	1	9	—	1
Totals	1,695	85,320	1,362	333

Fourteen species of ants were taken in association with *Ps. njalensis* and *Ps. citri* in the harvesting part of the experiment that were not taken on any of the 1,080 trees felled, but only two of these species belong to genera which had not been taken before (*Paedalgus—Myrmicinae,* and *Mylanderia—Formicinae*). The bulked results from the 1,295 pods with ant-attended *Ps. njalensis* are tabulated in Table 18, and it is of some interest in this respect that every species collected was actively tending the mealybugs at the time of collection. The seeming discrepancy between the number of pods (1,295) and the total number of ant collections (1,349) is due to the fact that 105 collections of individual ant species were taken as mixed colonies from only 51 pods. The balance of 1,244 pods supported one ant species each.

TABLE 18.

ANT COLLECTIONS FROM 1,295 *PS. NJALENSIS* INFESTED PODS.

Ant species.	No. of collections.
Crematogaster striatula ...	549
Cr. luctans	48
Cr. " 361 "	41
Cr. " 257 "	208
Cr. africana	54
Cr. 141 (*a*)	32
Other Cr. species	28
Pheidole megacephala ...	340
Other Ph. species	15
Other Myrmicinae ...	24
Dolichoderinae	6
Formicinae...	4
Totals	1,349

These results are of interest when compared to Tables 13 and 14 in view of the relative increase in importance of the Pheidoline ants as mealybug tenders. This is possibly due to an accumulation of mealybug infested pods growing on the trunks of trees near the ground, and thus within easy reach of the soil-nesting Pheidoles.

(*e*) *Parasitism of Ps. njalensis.*

Samples of adult mealybugs were taken from the collections made from harvested pods and felled trees. The mealybugs were kept in petri dishes and all parasites which emerged were recorded. The results are given in Tables 19 and 20. As far as can be ascertained at present there are two dipterous and at least four hymenopterous parasites involved in these collections, but accurate identifications depend on specialist examination and are not available at present.

TABLE 19.

PARASITISATION OF *Ps. NJALENSIS* FROM POD COLONIES.

Total Ps. njalensis examined	11,318
Diptera emerged	73
Hymenoptera emerged ...	66
Total parasites	139

These results give an " effective parasitism " of 1·2% for pod colonies of *Ps. njalensis.*

TABLE 20.

PARASITISATION OF *PS. NJALENSIS* FROM CACAO TREES.

RESULTS FROM 384 FELLED TREES INFESTED WITH *PS. NJALENSIS*

Total *Ps. njalensis* examined	22,926
Diptera emerged	55
Hymenoptera emerged ...	642
Total parasites	697

These results give an " effective parasitism " of just over 3% for the overall *Ps. njalensis* population. The difference between the tree and pod parasitisation rates may be an index of the " temporary " nature of pod colonies as distinct from the permanent nature of an established colony that remains settled in the canopy and is not subject to sudden extinction by harvesting—with a consequent decrease in adult parasites available for egg laying in the next generation of mealybugs.

2. Incidence of Vectors on Wild Food Plants.

Twenty-six new host plant records for *Ps. njalensis* have been made during the past year, bringing the total to date to 108 plant species. The new records are as follows :—

Antrocaryon micraster, Alstonia congensis, Artocarpus communis, Bandeiraea simplicifolia, Bosqueia angolensis, Carapa procera, Claoxylon hexandrum, Ficus sp., F. elastica, F. exasperats, Holarrhena sp., Khaya grandifolia, Lennea sp., Loranthus sp., Mussaenda erythrophyllum, Octolobus sp., Omphalocarpum sp., Piptostigma Proussei, Pouzolzia guineensis, Psidium guyava, Pycnanthus kombo, Rinorea sp., Tamarindus indicus, Tectona grandis, Terminalia ivorensis, Vitex Clenkowskii.

Table 21, below, gives the results from a number of visits to the host plant genera detailed in relation to the number of times *Ps. njalensis* has been collected from those genera. As such, it provides a slight indication of food preferences amongst wild host plants in the Eastern Province of the Gold Coast.

TABLE 21.

PS. NJALENSIS ON WILD HOST PLANTS.

Host plant genus.	Times visited.	Times with *Ps. njalensis.*	% with *Ps. njalensis.*
Canthium	21	20	95
Ceiba	25	6	24
Coffea	13	2	15
Cola	53	9	17
Ficus	22	5	23
Sterculia	16	4	25
Theobroma	1,080	384	36

If (from Table 11) *Ps. njalensis* occurs on approximately 36% of the cacao in the Tafo district, it is clear that *Canthium* is a preferred host, and further that after cacao, *Ceiba* and *Sterculia* are the next two preferred genera.

In view of the importance of *Canthium glabriflorum* as a secondary host of *Ps. njalensis* a number of these trees was felled and dissected and the numbers of mealybugs inside domatia and those feeding on the outside of branches, shoots and leaves were counted. From eleven mature *Canthium* trees so treated (girths 16 to 29 inches), it was calculated that two trees were supporting populations of less than 2,500 mealybugs, two trees had between 5,000 and 8,000 mealybugs, and the balance of seven trees were all supporting populations of between 13,000 and 18,000 mealybugs. It is thus clear that *Canthium* is an important wild reservoir of vectors.

3. The Wind Trap Experiment.

Five sticky stove-pipe wind traps have been put up in the field. Two are situated in a clearing in the cacao at Tafo, one in cacao at Oyoko, one on the hill top Aburi, and one on the old bauxite workings at the top of Mt. Ejuanema, Mpraeso. These traps are examined at fortnightly intervals and any coccid crawlers removed for confirmation of identity. To date the traps have been examined 17 times (i.e., the experiment has been in operation for eight and a half months), and a total of 148,671 arthropods have been collected from them. Of these, 6,208 were apterous forms of which 1,105 were referable to the Coccoidea—mostly to the pseudococcidae. There was a very marked increase in the numbers of Coccids obtained during the dry season

(December-March) as compared with the wet season figures, and this fact may prove of some importance with regard to the spread of cacao virus.

4. Minor Investigations.

(*a*) *The life history of Ps. njalensis.*

Life history investigations on *Ps. njalensis* have now been completed, and the results are summarised in Table 22.

TABLE 22.

PS. NJALENSIS—LIFE HISTORY.

Stage.	Mean Days.	Range (Days).	No. of trials.
1st Instar	7	4—13	74
2nd Instar	5	3—10	31
3rd Instar	7	5— 9	19
Adult to egg laying	22	18—30	9
Totals	41	25—50	9

After egg laying the mature females live for four to ten days before dying, though on one occasion a female survived for 27 days. The males emerge from pupation (6-8 days) at the same time as the young adult females emerge from the 3rd instar and copulation takes place within a few hours. Males have lived in captivity for a maximum of two days after emergence, with an average life of 24 hours. A life cycle of birth to egg laying of six weeks allows a maximum of eight generations a year—which is quite usual of Pseudococcid mealybugs in the tropics.

(*b*) *New Coccid records from Gold Coast cacao.*

Twelve new records of coccids attacking cacao at Tafo have been obtained during the year. These are :—

Aspidiotus destructor, Sign, *Aspidiotus sp. H*6085, *Aspidiotus sp. H*6086, *Aonidiella replicata,* Lind, *Hemiberlesia palmae* (Ckll.) *Hemiberlesia cyanophylli,* (Sign), *Pseudaonidia sp. H*6086 (a), *Selenaspidus sp. H*6031, *Lecanium sp. H*6038, *Inglisia sp. H*6397, *Pseudococcus longispinus,* T-T., and *Pseudococcus sp. H*6306. We are indebted to Dr. W. J. Hall for identifying most of these species.

(*c*) *Miscellaneous collections.*

Thirty-nine collections of coccids have been despatched to the Commonwealth Institute of Entomology during the year, and identifications of all of them have been received. Forty-one collections of ants have been despatched, and eight determinations have been received to date. There is need for the full time services of a myrmecologist to work at the British Museum on the West African coccid-tending ants.

CONTROL.

Tafo Station.

Monthly inspection, and the removal of trees showing swollen shoot symptoms has continued on the Old Station. Table 23 brings up to date the data recorded in previous annual reports.

TABLE 23.

OUTBREAKS OF SWOLLEN SHOOT ON THE OLD STATION.

Month.	New outbreaks.	Trees Destroyed.		Total.
		New outbreaks.	Old outbreaks.	
April, 1947	8	13	20	33
May	6	13	11	24
June	5	5	5	10
July	1	2	8	10
August	4	5	10	15
September	5	6	6	12
October	4	4	25	29
November	3	3	52	55
December	10	26	34	60
January, 1948	4	7	24	31
February	2	6	15	21
March	8	13	24	37
Total 1947–48	60	103	234	337
„ 1946–47	69	92	174	266
„ 1945–46	40	56	160	216
„ 1944–45	47	53	117	170

Inspection and cutting out swollen shoot diseased trees has continued on the New Acquisition. Table 24 records the relevant data.

TABLE 24.

CACAO CUT OUT ON THE NEW ACQUISITION 1947/48.

Standing cacao April 1st, 1947 (acres)	299·1
Diseased trees cut out April 1st, 1947 to March 31st, 1948 ...	5,339
Contact trees cut out April 1st, 1947 to March 31st, 1948 ...	2,624
Area represented by diseased and contact trees (acres)	10·4
Area cleared for building and other purposes (acres)	12·8
Standing cacao March 31st, 1948 (acres)	275·9

Cacao farms just outside the Station's boundaries are all now heavily infected with swollen shoot and undoubtedly act as a reservoir of infection for spreading the disease to the cacao on the Station.

Though re-infection remains somewhat heavy on mature trees in the Old Station and New Acquisition it is encouraging to note that infection on the young cacao is slight. Table 25 gives the figures for the incidence of swollen shoot disease on the Institute's young cacao.

TABLE 25.

INCIDENCE OF SWOLLEN SHOOT ON YOUNG CACAO.

Station.	Date planted.	Approx. No. of plants.	Diseased Plants.						Total.
			1942/43.	1943/44.	1944/45.	1945/46.	1946/47.	1947/48.	
Akwadum	1942	28,000	—	1	2	2	2	47	54
Koransang	1945	15,000	—	—	—	3	31	72	106
Kukua	1945	50,000	—	—	—	—	1	23	24
Nankesi	1945	35,000	—	—	—	—	1	2	3
Adonkwanta ...	1945	56,000	—	—	—	—	12	60	72
Tafo (Old Station)	1940–1947	85,000	—	—	—	—	1	2	3

Out of a total exceeding one quarter of a million young cacao plants only 262 have become infected over a period of three years or more. The three cases recorded at Tafo (Old Station) occurred among the First Progeny trial—planted 1940—and no swollen shoot disease has yet been found among any of the numerous supplies filling the gaps caused by cutting out mature diseased trees.

SECTION III.

CAPSID RESEARCH.

General.

The most striking feature of the year has been the low numbers of *Sahlbergella singularis* and *Distantiella theobroma* in the cacao under observation in the Eastern Province of the Gold Coast.

Routine collections have been so low that it has been extremely difficult to obtain bugs for laboratory experiments. It is interesting to note that the capsid populations have shown a steady decline each year since the present collection system started in 1944.

There was little damage to foliage although a very large proportion of the pods were damaged by *Helopeltis* sp., and by *Bryocoropsis laticollis* but very few were attacked by either *S. singularis* or *D. theobroma.* Similarly, in Nigeria, the collections at Owena were much lower than they were during 1946-47.

Population Studies.

Routine Collection.

In the past the earlier recorded preferences of *S. singularis* and *D. theobroma,* viz., the former on old cacao and the latter on young cacao, have been accepted. Consequently any *D. theobroma* occurring on old trees, or *S. singularis* on seedlings were ignored by the collectors as being negligible. From November both species were collected from all the trees examined to give a numerical estimate of the assumed preference.

At Tafo the collections could not be made in the usual areas for a part of February and the whole of March. The February figures given below are based on fifteen days' records only, and none was obtained for March.

Table 26 gives a summary of the mean monthly population changes. The last column, Pods per 100 trees, is included to give an indication of seasonal pod production.

TABLE 26.

Month.	*S. SINGULARIS.*		*D. THEOBROMA.*		Pods per 100 Trees.
	Per 100 Pods.	Per 100 Trees.	Per 100 Pods.	Per 100 Seedlings.	
April, 1947 ...	0·7	1·6	1·1	5·4	10
May	0·7	1·0	0·7	7·7	10
June	1·3	1·1	0·1	6·4	19
July	1·6	1·3	0·3	3·7	109
August ...	2·3	3·2	0·3	2·6	531
September ...	2·7	1·3	0·5	4·7	263
October ...	6·3	2·8	1·5	3·6	104
November ...	9·0	2·7	1·5	5·4	30
December ...	5·2	2·4	0·3	4·9	9
January, 1948 ...	2·3	1·8	1·0	2·4	1
February ...	2·5	1·1	0·0	2·7	1

As in previous years the largest fluctuations have been in the pod population, and these are naturally correlated with the presence of developing pods. The population ranges on the vegetative parts of the trees are in marked contrast to previous years' records in their stability. After removal of the 1944 crop there was a sharp rise in vegetative population to 58 capsids per 100 trees, and a similar rise was recorded in the following year. The 1946 period showed only a small increase, but the maximum of 12 in that year is still much higher than the maximum of 2·8 recorded here.

Comparable figures for Owena are given in Table 27.

TABLE 27.

Month.	*S. SINGULARIS.*		*D. THEOBROMA.*		Pods per 100 Trees.
	Per 100 Pods.	Per 100 Trees.	Per 100 Pods.	Per 100 Seedlings.	
April, 1947 ...	3·4	4·0	0·2	0·8	161
May	2·7	4·0	0·1	0·2	248
June	3·1	4·5	0·0	0·0	416
July	3·2	3·3	0·0	0·1	473
August ...	3·5	3·0	0·0	0·0	384
September ...	5·5	2·9	0·1	0·0	178
October ...	6·2	3·0	0·3	0·2	74
November ...	10·0	5·3	1·0	0·8	39
December ...	10·1	4·9	0·9	0·8	27
January, 1948 ...	8·7	4·1	1·3	1·0	25
February ...	8·9	4·9	0·7	0·8	51
March	4·5	4·0	0·3	0·5	124

The complete collections instituted in November gave the results summarized in Tables 28 and 29.

TABLE 28 (TAFO DATA).

Month.	*SAHLBERGELLA SINGULARIS.*			*DISTANTIELLA THEOBROMA.*		
	Per 100 Pods.	Per 100 Trees.	Per 100 Seedlings.	Per 100 Pods.	Per 100 Trees.	Per 100 Seedlings.
November... ...	9·0	2·7	26·8	1·5	0·4	5·4
December ...	5·2	2·4	17·4	0·3	0·3	4·9
January	2·3	1·8	11·4	1·0	0·4	5·4
February	2·5	1·1	3·4	0·0	0·4	2·7

TABLE 29 (OWENA DATA).

Month.	*SAHLBERGELLA SINGULARIS.*			*DISTANTIELLA THEOBROMA.*		
	Per 100 Pods.	Per 100 Trees.	Per 100 Seedlings.	Per 100 Pods.	Per 100 Trees.	Per 100 Seedlings.
November... ...	10·0	5·3	17·4	1·0	0·8	4·2
December ...	10·1	4·9	23·8	0·9	0·8	6·0
January	8·7	4·1	21·9	1·3	1·0	5·7
February	8·9	4·9	28·9	0·7	0·8	5·2
March	4·5	4·0	25·4	0·3	0·5	3·4

It will be seen that the number of *S. singularis* on seedlings is considerable, and that *D. theobroma* does attack the vegetative parts of mature trees consistently although only to a small extent.

As will be seen from Tables 30 and 31, *D. theobroma* in its own distribution does show a marked preference for seedlings in comparison with *S. singularis*. This preference is statistically significant at P=0·01.

NOVEMBER TO FEBRUARY TOTALS.

TABLE 30 (TAFO DATA).

	S. singularis.	*D. theobroma.*	Total.
Pods	1,037	157	1,194
Trees	2,881	481	3,362
Seedlings	2,156	738	2,894
Total	6,074	1,376	7,450

TABLE 31 (OWENA DATA).

	S. singularis.	*D. theobroma.*	Total.
Pods	2,209	220	2,429
Trees	3,209	559	3,768
Seedlings	1,967	452	2,419
Total	7,385	1,231	8,616

The routine collections give no indication of population changes in the canopy as the upper limit of examinaton is about six feet from the ground. To supplement the collection records, counts of fresh lesions were made on a sample number of twigs from each tree cut down on the Mealybug Population Plots, between September and February—Table 32.

TABLE 32.

Month.	CHUPON.			FAN.			Number of Pods harvested.
	No. Examined	% with lesions.	Mean No. lesions per chupon.	No. Examined.	% with lesions.	Mean No. lesions per fan.	
September	132	81·8	9·9	470	87·7	8·7	6,598
October	154	46·8	6·5	501	43·1	5·1	10,453
November	115	47·0	6·5	466	41·8	4·9	5,595
December	114	70·2	8·3	470	54·0	4·8	1,775
January	60	66·7	7·0	480	65·6	4·0	1,166
February	73	47·9	5·8	468	34·4	4·0	125

The changes with time are statistically significant showing lower levels of infection in October, November and February. The February fall is undoubtedly due to the low population of capsids at that time of year. The fall in October and November, on the other hand, is most probably correlated with the large number of pods on the trees, a return to vegetative feeding taking place in December and January when most of the pods have been harvested.

Table 32 shows that extensive feeding damage occurs in the canopy, but it appears to be an unimportant breeding site. All twigs examined for lesions were stripped of the bark and the presence of eggs noted—Table 33.

TABLE 33.

	Number Examined.	Number of eggs.	%
Chupon	648	15	2·3
Fan	2,855	0	0·0

Significant difference would be ± 0·85%.

The results show that chupons are fed upon more intensively than fans, and that they are also more important as breeding sites.

Observation Plots.

Sufficient data are accumulating from the Observation Plots to enable this series of observations to cease within the next two months. Results to date indicate that:—

1. Capsid pockets are permanent foci of capsid populations.

2. The fluctuations in the number of bugs within a pocket follow the same trends as those shown by the collection of results, namely, with a well-marked peak at the time of main crop and for a short while afterward, and a less well-marked peak at mid-crop.

3. These fluctuations are independent of the presence of pods in the pocket, a build-up of nymphs taking place on chupons in the badly damaged plots.

4. There is a tendency to an aggregation of capsids within the pocket, even when the surrounding healthy cacao is in full bearing.

5. A break in the canopy is one of the factors determining the formation of pockets. These have been produced experimentally by pollarding and by the liberation of a large number of capsids in a restricted area.

6. Within the pocket equilibrium is maintained by a high nymphal mortality. Much of this is due to attack by general predators and through starvation caused by the die-back of chupons after intensive feeding.

7. Adults developing within pockets move freely in and out of the surrounding cacao.

Regeneration of Capsid Pockets.

In those capsid pockets where the affected trees were coppiced the chupon growth from the stumps has been vigorous. 85% of the coppiced stumps produced chupons, and seedlings planted to replace deaths are growing well but are small compared with the chupon growths.

The chupons have been thinned to two or three per stump and no capsid damage has been seen since they were treated with D.D.T. emulsion.

Macromischoides Field Experiment.

In this experiment, designed to see if the ant, *Macromischoides aculeatus* exercises any control on capsids, the cacao was planted in February, 1947, and is becoming well established.

As this experiment is designed to investigate any protective capacity of these ants on mature or young trees it was felt that all steps should be taken to ensure that the cacao really did become established. When capsids appeared on the seedling cacao it was treated with D.D.T.; no more capsids or damage have since been seen.

Capsid Physiology and Feeding Behaviour (*S. singularis*).

Preliminary work consisted of the examination of lesions of various ages in cacao stems.

Hand-cut sections of wax embedded material were stained with light green in clove oil. It has been confirmed that the cortical medullary rays and parenchyma are destroyed by the salive of the capsid.

A number of observations has been made on the feeding of the capsids, caged in 1″ glass boiling tubes with pieces of cacao stem. It has been found that the globules of fluid observed (which average ·364 cubic mm. in volume) are partly the faeces of the capsids and partly a regurgitation through the mouth parts which occurs every three or four feeds. Exudation from the plant tissue of the lesion seems to be insignificant. The habit of the capsids (as observed on 4th instar for the most part) is to remain about one spot for considerable lengths of time, feeding for periods of 20 to 30 minutes with rests of up to five minutes. At temperatures of 76-77° F. feeds are prolonged to about 40 minutes and at 82-83° F. they are shortened to about five minutes with long resting periods. Third instar nymphs feed (at 78-80° F.) for periods of 10-15 minutes with very short rests. Forty-six observations have been recorded. The capsid moves its feeding place slightly with each feed and causes large contiguous areas of damage. At 84-86° F. the nymphs are very active and sensitive to light, and feeding ceases, to be resumed when the temperature falls. Long periods of high temperature may cause hunger stimulus to overcome the inhibition of feeding by heat. It is hoped to investigate the effects of this behaviour pattern on the seasonal variation in abundance of the capsids.

Morphology of Capsid Eggs.

Source of Material.

One hundred eggs of each of the four common cacao capsids were examined, with the object of fining morphological differences by which eggs collected in the field may be assigned to the appropriate species.

Succulent chupons were supplied daily to four cages containing adults of *D. theobroma, S. singularis, B. laticollis* and *Helopeltis rubrinervis* respectively. The bark was stripped from these chupons after 24 hours exposure in the cages and the eggs, which could then be seen from the underside, were carefully dissected from the plant tissues.

Specimens of the eggs of *Helopeltis bergevini* and *H. westwoodi* were not obtained.

General Description.

In all the species under consideration the egg is considerably longer than broad, somewhat laterally flattened, and with the long axis slightly curved so that the ventral surface is concave. The anterior end is closed by an operculum of clear brittle material which can readily be broken away from the rest of the egg. In the wall of this operculum are several flask-shaped vacuoles the function of which is doubtful.

From the dorsal and ventral surfaces of the egg, immediately behind the base of the operculum, two long thin processes bearing numerous micropyles, project forward.

Inter-specific differences.

Capsid eggs collected from cacao stems can rapidly be determined as being either *S. singularis* or *D. theobroma* by microscopic examination without resort to measurement. In the former species the operculum has less than twenty vacuoles, each about five times as long as broad and all reaching the outer surface along the dorso-ventral ridge whereas in the latter species the vacuoles, which are of similar shape, are much more numerous and are distributed over the apical 2/3 of the operculum. In this case the frequent overlapping of these vacuoles within the thickness of the wall of the operculum creates the impression of striations.

In both *B. laticollis* and *H. rubrinervis* the vacuoles are about twice as long as broad, and are distributed over most of the operculum. These species may be distinguished by the fact that in the former the micropylar processes are sub-equal whereas in the latter the dorsal process is considerably shorter than the ventral.

Specimens of *B. laticollis* have been found which might be confused on this basis with those of *H. rubrinervis* and a safer method of determination is by the use of micrometer measurements on which the following key is based :—

1.	Total length of egg (excluding micropylar processes) greater than 1·8 mm.	2
	Total length of egg (excluding micropylar processes) less than 1·8 mm.	3
2.	Ventral process longer than 0·84 mm.	*D. theobroma.*
	Ventral process shorter than 0·84 mm. ...	*S. singularis.*
3.	Ventral process longer than 0·66 mm.	*H. rubrinervis.*
	Ventral process shorter than 0·66 mm. ...	*B. laticollis.*

Alternative Hosts.

Sahlbergella singularis.

Fruits of *Sterculia foetida*, Linn., collected by A. F. Posnette at Asuansi had capsid nymphs and feeding punctures on them. Lesions and cankers were also noticed on twigs. One nymph was reared to the adult stage and proved to be *S. singularis*, Hagl. This is the first record of this species breeding on *S. foetida*, which is an introduced tree.

Adult female *S. singularis* were caged on the following possible alternative host-plants.

Bombax, sp., Cistanthera papaverifora, Triplochiton scleroxylon, Cola cordifolia, C. nitida, C. togoensis and Ceiba pentandra.

Eggs were laid on all the plants and except in the case of *Bombax*, sp., a reasonable hatch was obtained. The resulting nymphs rarely developed beyond the second instar and only on *Cola cordifolia*, *C. nitida* and *Ceiba pentandra* did any of the nymphs complete their life-cycle. The duration of the life-cycle on these plants varied little from the average of 40 days observed on cacao.

Bryocoropsis laticollis, Schum.

An interesting record of this species was made by K. O. Darko, who found several nymphs feeding on the fruits of *Piptastigma*, sp., probably *Preusii* (Engl. & Diels).

This under-storey tree which belongs to the *Anonaceae* was growing at a considerable distance from cacao in a Forest Reserve some 30 miles from Tafo.

The nymphs died before becoming adult, but there is little doubt that they were *B. laticollis.*

Several specimens of a capsid very similar to *B. laticollis*, except for their small size, were found by G. D. Adigbli on the fruits of *Cnestis* sp., probably *longiflora* (*Connaraceae*) in Nigeria. Specimens are being sent to the British Museum for determination.

Forest Reserve Cacao Plots.

Early in 1946 permission was requested from the Forestry Department of the Gold Coast to plant small cacao plots in Forest Reserves as remote from established cacao as possible. The intention was to simulate the conditions which existed when cacao was first planted in the colony. It was hoped that these plots would show whether the cacao became as quickly infested by capsids as it does in areas where the established crop may normally provide a reservoir of bugs, and also whether the forest trees from which any infestation emanated could be located.

The Pra-Anum Reserve on the Ashanti-Eastern Province border was finally selected as being the most satisfactory, and in August, 1946,

permission was given to clear and plant two half-acre plots in this reserve. The plots are approximately five miles from the village of Amentia on the river Pra and at least three miles from the nearest cacao farms.

Two sites were chosen—one on low-lying, poor, transported grey sand and another on higher ground with a good red sedentary soil. Very few tall forest trees were present and clearing was restricted to shrubs and small trees. No artificial shade was planted and the ground was not burnt over. Cacao seed at stake was planted two feet by four feet in August, 1946, and germination was good.

In December, 1946, the seedlings were found to be growing well and in June, 1947, the tallest cacao was between three and four feet high. No sign of capsid damage was seen. During December, 1947, the plots were again visited, and although growth had been irregular the best cacao in both plots was growing extremely well, and in some cases was six to eight feet high. The plot on the higher ground was the better of the two, the growth on the other being very irregular.

No typical *D. theobroma* or *S. singularis* damage was found at this time, but many plants bore small feeding marks similar to those made by capsids. A small amount of die-back was present but only on the smallest growing points.

A number of adult *H. westwoodi* were caught amongst the cacao plants and there can be no doubt that this insect was responsible for the damage. This species has only once before been found on cacao in the Gold Coast (Tafo, 1943) and at least once by Golding* in Nigeria. Extensive damage by *Helopeltis*, spp., to the vegetative parts of cacao is rare even when the insect causing the damage is the common *Helopeltis*, sp., which is normally associated with cacao pods.

There was no evidence that the *H. westwoodi* had become established on the cacao. No eggs or nymphs were found during an extensive search, and it must be presumed that the adult capsids were responsible for the damage.

Chemical Control.

In the 1946/47 Annual Report the results of some preliminary experiments on the use of D.D.T. emulsions on young cacao plants were included. These results showed that, by taking advantage of the residual effect displayed by this insecticide, it appeared likely that an economic control of the capsids on young cacao was possible. Several experiments were laid down to test the painting technique evolved and all have given successful results.

Commercial emulsifiable concentrates containing up to 25 per cent. D.D.T. became available, and these have been used in all the

* Golding F. D. (1947). "Further notes on the food plants of Nigerian insects VI." Bull. Ent. Res. XXXVIII : 78.

experiments. The technique used is simple, the concentrate is diluted with water to 2·5 per cent. D.D.T. and the milky emulsion so obtained is painted on the young trees. Special attention is paid to the forks and branch unions as it is known that the older nymphs seek shelter in those places from the heat of the sun. When the solvent and water has evaporated a film of D.D.T. is left which is toxic to any bug remaining on it for a sufficient length of time. Painting does not signify any careful brushing as the liquid is swabbed on quite liberally and spreads rapidly.

Materials used.

Many different 20 per cent. and 25 per cent. D.D.T. concentrates have been tried experimentally, and apart from varying difficulties in the rapid compounding of the dilute 2·5 per cent. emulsion there appeared to be little difference in their efficiency. It is believed that most of the concentrates sold commercially are made to the following formula :—

Solvent	...	...	...	...	65	parts	by	weight.
D.D.T.	...	...	...	...	25	„	„	„
Emulsifier	...	...	...	...	10	„	„	„

Most were simple to dilute, a good stable emulsion being formed with a minimum of agitation when water was added. Others required a greater degree of agitation or special mixing, and, although when finally made up they were as effective, it is felt that the extreme simplicity of the former types make their choice automatic if they are to be used by illiterate labour.

Experimental Results.

(1) *D.D.T. painting in the Rejuvenation Plots at Tafo.*

Six one-eighth acre plots, planted in 1942, and each containing 135 trees, were painted in November, 1946, and six similar plots were left as controls. Each week, the capsids seen in the plots were carefully counted and the numbers recorded.

Over five months, 88 per cent. of the capsids seen were on the untreated plots and only 12 per cent. on the treated. The greatest number seen at any one time on the untreated plots was 1,487 bugs in January, 1947. This represents an average of 248 capsids per plot (1·8 per tree), a number sufficient to do considerable damage. At the same time 193 bugs were seen on the treated plots, an average of 32 per plot (0·23 per tree). At the end of May, after a period of five months, the numbers on the treated plots had risen higher than those on the untreated. It was obvious that the D.D.T. film was no longer effective and the rapid rise in numbers was due to this and to the protection which had been given to the trees in the treated plots. These trees had grown well during the time of protection and had numerous young shoots attractive to the capsids. The untreated trees were stunted and very little young tissue had been left.

Repainting immediately reduced the numbers of insects to negligible figures.

(2) *Akwadum.*

Control of the capsids on the young cacao in this experimental farm had been tried by hand-picking, but the results were not successful. Collections were made once a fortnight and the bugs found were sorted into their respective instars. Examination of the figures obtained, Table 34, showed that, as the first and second instar nymphs are so small and their habits so secretive, the majority are missed unless the search is very expertly conducted or greatly prolonged.

TABLE 34.

CAPSIDS COLLECTED AT AKWADUM, 1946.

Species.	INSTARS.				
	1st.	2nd.	3rd.	4th.	5th.
D. theobroma ...	80	302	955	1,375	1,639
S. singularis ...	9	17	90	116	106

From the figures obtained in other population studies it is known that, in capsid colonies, there is a high nymphal mortality due to predaceous insects, unfavourable weather and other causes. It is obvious, therefore, that hand-picking misses a high proportion of early instar nymphs.

Because of the lack of success with hand-picking at Akwadum it was decided to paint all suitably sized trees on the station. From the previous hand-picking records it had been seen that those quarter-acre plots (into which the farm is divided) in the north-east corner were regularly and most severely attacked.

Four quarter-acres in this area were experimentally painted and one in the centre of the block was left unpainted as control. Hand-picking ceased on the rest of the farm but it was continued on this experimental block so that an estimate of the insecticidal effect of painting could be obtained.

First treatment was in January, and it was not until seven months had elapsed that it became apparent from the rapidly rising numbers of capsids in the treated plots that the toxic effect of the film had been so reduced as to make a second treatment imperative. Retreatment in September caused an immediate decrease in the number of capsids.

TABLE 35.

NUMBER OF CAPSIDS FOUND IN THE AKWADUM PLOTS. CACAO PLANTED 1942.

	Average number of capdids per Plot per collection.		
	Before treatment (34 collections)	After first treatment (15 collections)	After second treatment (9 collections)
Treated plots (four in number) ...	21	4	6
Untreated Control Plot	33	53	126

(3) *Comparison of effectiveness of different concentrates.*

Table 36 records the results of trials from four commercial concentrates A, B, C and D. The test plants were chupons growing from stumps which had been coppiced during the course of another experiment. Such chupon growth is, of course, vigorous and forms an attractive food supply for capsids. Five blocks of coppiced cacao were selected and each block divided into five sub-blocks. The treatments were distributed at random amongst the sub-blocks. Counts were made of capsids seen on the chupons in each sub-block at fortnightly intervals over one year from the date of the first application which was in February, 1947. The concentrates were again applied in June, 1947, and in January, 1948.

As the sub-blocks contained varying numbers of chupons the figures for " Capsids Seen " in Table 36 have all been reduced to the number seen per 100 chupons.

TABLE 36.

Treatment.	Capsids Seen. Per 100 Chupons.
A	30
B	24
C	26
D	31
E (Control)	198

There is obviously little difference in the effectiveness of the various solutions although the solvents and emulsifiers used in their manufacture were widely different.

(4) *Large Scale Field Test.*

The Institute's experimental substation at Adonkwanta is about 26 acres in extent and is divided almost in half by a motor road. Capsid damage is present in mature cacao surrounding the farm.

This farm was planted in 1945 and the growth of the seedlings has been irregular but mainly good. When the farm was laid out it was decided that the portion on the north side of the road would be left to grow without any control measures against swollen shoot infection or capsids.

In August, 1947, the whole of the southern section containing approximately 20,100 seedlings 18 inches or more in height was painted with the 2·5 per cent. D.D.T. solution. The northern section with some 23,800 seedlings was left untreated and capsid damage became apparent there. In November, three months after the initial treatment, a count of the capsids present showed that there was one capsid per 17 seedlings in the untreated section and one capsid per 168 seedlings in the treated half. The number of capsids increased in January, 1948, indicating a reduced toxicity of the D.D.T. film; the seedlings were therefore repainted.

In February, 1948, an examination was made of every plant on the farm, and Table 37 shows the results obtained.

TABLE 37.

	Total number of seedlings.	Undamaged.	Damaged.	Percentage damaged.
Treated Section ...	20,071	19,889	182	0·8
Untreated Section	23,854	19,783	4,071	17·1

The damaged seedlings in the untreated half of the farm were scattered, with areas of intense damage where many plants had been killed.

Cost of Treatment.

The following table will give an idea of the cost of this method of control:—

TREATMENT OF EXPERIMENTAL FARMS AT NANKESE, KUKUA, ADONKWANTA AND KORANSANG.

Number of plants treated (average height 2½ feet) ...	110,407
Number per man-hour	114
Amount of concentrate used (pints)	30
Amount of water used (gallons)	34
Labour cost per 100 plants at 2/6d. per man-day (pence)	3·3
Insecticide cost per 100 plants at 35/- per gallon ...	1·4
Number of plants per gallon of concentrate ...	25,000-30,000

General Observations.

All the young cacao on the Institute's lands has now been treated and trial supplies of emulsifiable concentrates have been supplied to the Departments of Agriculture of the Gold Coast and Nigeria.

At the advised strength (2·5 per cent. D.D.T.) there is a very slight browning on very young flush-tissue, but it appears to be merely a surface action with little or no harmful effect. Experience has shown that new growth, subsequent to treatment, is liable to attack by capsids. This damage is frequently due to the feeding of adults and to the feeding of young nymphs hatching from eggs laid in the untreated tissue. Damage of this nature is not usually serious.

THRIPS COUNTS AT OWENA.

Introduction.

Early in 1947 it was noticed that cacao trees which were growing in the complete absence of overhead shade in certain parts of the Owena district were in an exceedingly poor state of health. These trees were subject to frequent severe defoliation and had numerous dead twigs and branches projecting above the living wood. An examination of the area failed to reveal sufficient capsid lesions to cause such devastation, but cacao thrips (*Selenothrips rubrocinctus*) appeared to be more numerous there than in shaded situations nearby. As it was thought possible that thrips damage might be an important contributory factor in the deterioration of the cacao canopy an experiment was designed to investigate whether thrips were more prevalent on unshaded than on shaded cacao in the district.

The Plots.

Three plots were selected as follows :—

Plot I.

Under moderate overhead shade of forest trees, cola trees and oil palms. The cacao in this plot was in good condition and had a reasonably intact canopy.

Plot II.

Completely unshaded cacao.

Plot III.

Cacao under very dense overhead shade.

No plot boundaries were defined as Plots II and III are located in the same area on which a considerable amount of food farming occurs. Plot III includes any trees growing beneath the clumps of oil palms and cola trees which are scattered throughout the area and which provide very heavy shade.

Sampling Technique.

One hundred mature leaves, chosen at random, were examined on each plot on two occasions in each calendar month and the number of adult thrips and nymphs on each was noted. The word " nymph " is used in this experiment to describe all immature stages of thrips other than eggs. A record was also made of thrips damage to the leaves. Damage was classified as " nil," " slight " or " severe." Flushing was noted but flush leaves were not examined until they had hardened, as such leaves are very rarely attacked by thrips. The first count was made on 16th April, 1947.

Results.

A preliminary examination of the data obtained to date has been made and the following results have been obtained.

Population fluctuations.

The thrips population reached a maximum in all plots during the period from late December, 1947, to mid-February, 1948. The most rapid rise was noticed in Plot II when the population rose from 48 thrips per 100 leaves in November to 166 thrips per 100 leaves in December. The slowest and least pronounced rise occurred in Plot III.

The minimum population occurred in Plots I and II at the end of July, while in Plot III only eight thrips were found during the two months from the end of September to mid-November.

A significant negative correlation exists between thrips numbers and rainfall and a more significant result has been obtained by correlating the thrips population with the rainfall for the previous month.

Frequent minor changes in thrips numbers have been noticed. Such changes may be due to—

(*a*) a rise and fall of successive generations of thrips;

(*b*) changes in the numbers of leaves per tree due to flushing or defoliation;

(*c*) sampling errors.

Insufficient data are available at present to determine which of these factors is the most important.

Comparison of data from different plots.

Table 38 gives the mean values per 100 leaves of nine "populations" estimated separately for each plot from 22 samples taken between April, 1947, and February, 1948, inclusive.

TABLE 38.

Per 100 leaves.	PLOT I. Light Shade.	PLOT II. No Shade.	PLOT III. Heavy Shade.
	Mean.	Mean.	Mean.
No. of Adults	11·4	29·1	7·4
No. of Nymphs	17·3	54·9	4·9
Total Thrips	28·7	84·0	12·3
Leaves with adults only	1·8	3·7	2·3
Leaves with nymphs only ...	2·6	3·2	0·9
Leaves with nymphs and adults...	3·8	5·6	1·5
Total leaves with thrips	8·2	12·5	4·7
No. of severely damaged leaves ...	10·8	22·7	2·4
Total damaged leaves	49·1	63·8	27·2

Statistically significant differences between plots occurred as follows:—

(*a*) All mean values calculated for Plot I were less than those for Plot II except in the case of leaves with nymphs only.

(*b*) All mean values calculated for Plot I were greater than those for Plot III except in the case of leaves with adults only, when the value found for Plot III was the greater, though not significantly so.

(*c*) All mean values calculated for Plot II were greater than those for Plot III.

These facts agree well with the hypothesis that thrips and thrips-damage occur most frequently on the unshaded deteriorated cacao.

It is also noted that the percentage of nymphs in the plots was higher in unshaded than in shaded cacao, the calculated values for the three plots being :—

Plot I, 62·5 per cent. Plot II, 65·1 per cent. Plot III, 39·8 per cent.

This might indicate that heavily shaded cacao is not a suitable breeding place for thrips.

SECTION IV.

SOIL SCIENCE AND CHEMISTRY.

Soil Science.

At the request of the Oil Seeds Mission and of the Gold Coast Government a considerable portion of the period under review was spent in surveying possible ground-nut areas in the Gold Coast. A report on these areas has been presented by the Senior Soil Scientist to the Mission.

In view of transfer to the Gold Coast Government of the Senior Soil Scientist in April, 1948, the activities of the Soil Science staff were spent in completing the records of soil surveys carried out during the past three years and in preparing data for publication.

Chemistry.

A large part of the Chemist's time has been occupied with problems of laboratory equipment and design. Shortage of essential apparatus and chemicals has hindered work considerably but the position is slowly improving. The available laboratory space is being loaned to the Department of Agriculture for routine soil analytical work in connection with the Soil Survey of the Gold Coast but the Institute Cartography room is at present being converted into a chemical laboratory.

A butter-fat survey of the Progeny Trials and Trinidad Introductions at Tafo, has been commenced. It is hoped to supplement those results with an alkaloidal survey as soon as possible.

Butter-fat estimations on individual trees in the First Progeny Trial and Trinidad Introduction plots were carried out during the 1947-8 main crop season.

First Progeny Trial.

History.

The trees concerned in the above trial are the selfed progeny of thirty high-yielding West African Amelonado trees selected from Experimental stations. They were planted in the field in March, 1939, unselected Amelonado seedlings being planted as controls. Later, two selections, possibly hybrids, were included, viz., the selfed progeny of N.38 (the best Nigerian selection) and the selfed progeny of E.1 (the first local hybrid selection to give seed).

Twenty-five of the thirty-one progenies produced pods during the 1947-8 main crop season but unfortunately none of the controls. Bulked samples of West African Amelonado cacao harvested from November, 1947 to February, 1948 were therefore used as controls.

The key to the selections is as follows :—

A=Aburi, N=Nigerian, P=Kpeve, S=Asuansi, E=Effiduase.

Experimental Procedure.

A single pod from a single tree of each progeny was obtained, the beans freed from mucilaginous material, the seed coats removed and the cotyledons plus radicles dried in an electric oven at 110° C. for 24 hours. The dried beans were then bottled and stored in desiccators to await analysis.

The method of estimation was essentially that of Humphries (Eighth Annual Report on Cacao Research, Trinidad, 1938) with minor modifications which were dictated by availability of apparatus and chemicals.

The dried beans were minced and ground in a mortar until the mass passed through a 2mm. sieve. Duplicate 5·00 grm. portions were weighed out and extracted in a soxhlet apparatus for 20 hours with 150 cc. light petroleum bp. = 60-70° C.* The solvent was distilled and the residue (A) dried to constant weight at 110° C.

The residual powder was thoroughly mixed with half its weight of freshly-calcined MgO, 10 cc. distilled water added and all particles of the mixture wetted. This thin paste was partially dried on an electric hot plate for 30 minutes, wrapped in a fat-free filter paper and extracted for a further 20 hours with 150 cc. chloroform in the thimble used for the first extraction. After distillation, the weighed residue (B) consists of butter-fat plus alkaloids, the former being removed by allowing the mixture to stand overnight in 100 cc. light petroleum bp.=60-70° C.

The fat-free residue (C) is now weighed. The total weight of butter-fat obtained is represented by A+(B−C).

Experimental Results.

Percentages are calculated on the unfermented, oven-dry nib.

It will be appreciated that the percentage butter-fat recorded in Table 39 refers only to single trees and cannot therefore be accepted as necessarily representing the average butter-fat content of beans from a true sample of each progeny. The figures do, however, give an indication of the variability in butter-fat content that may be expected. True samples will have to await the time when most of the individual trees in each progeny have come into bearing.

* Light petroleum bp. = 60–70° C. was the only fraction available, the portion distilling between 60–70° C. was used for the experiments described.

TABLE 39.

Plot No.	Stand No.	Selfed progeny of selection.	Date of Harvesting.	Per cent. Cacao Butter.		
				Light Petroleum. extract.	Chloro-form extract.	Total.
			1947.			
1 11/3	64	A 187	8th Sept.	50·96	3·28	54·24
I 11/3	84	S 53	,,	50·32	2·60	52·92
I 11/3	3	A 176	,,	48·90	4·36	53·26
I 11/3	100	A 196	,,	47·32	6·76	54·08
I 11/3	96	P 5/8	,,	50·82	1·62	52·44
J 11/4	25	P 3/9	,,	45·98	7·14	53·12
J 11/4	38	A 139	,,	49·20	5·64	54·84
J 11/4	45	A 20	25th Sept.	48·76	2·24	53·00
J 11/4	15	S 84	,,	49·48	2·74	52·22
J 11/4	19	A 121	,,	48·68	3·86	52·54
J 11/4	36	S 132	,,	46·10	5·56	51·56
J 11/4	95	A 220	,,	50·68	2·72	53·40
J 11/3	81	P 3/7	14th Nov.	48·64	3·58	52·22
J 11/4	65	P 2/3	,,	48·88	6·40	55·28
J 11/4	84	A 164	,,	47·10	6·38	53·48
J 11/4	42	S 5	,,	50·86	1·38	52·24
J 11/4	2	P 5/12	,,	48·48	4·20	52·68
J 11/4	21	N 38	,,	48·76	2·55	51·31
				51·30	0·84	52·14 Av. = 51·72
K 11/4	98	P 4/9	,,	49·74	3·82	53·56
K 11/4	85	E 1	,,	51·56	3·66	55·22
J 11/4	49	S 72	,,	49·02	6·96	55·98
J 11/4	51	P 3/15	8th Dec.	48·72	5·22	53·94
			1948.			
K 11/4	35	A 218	15th Jan.	48·44	4·72	53·16
K 11/2	30	S 45	,,	47·82	5·70	53·52
L 11/3	49	S 52	,,	47·56	4·14	51·70
Controls: Bulked samples of unselected Amelonado cacao harvested at Tafo.			1947.			
			21st Nov.	50·14	2·84	52·98
			5th Dec.	45·72	5·00	50·72
			1948.			
			16th Feb.	49·20	3·34	52·54
				Average		52·08

Trinidad Introductions.

History.

One hundred and two cacao selections were sent from Trinidad during December, 1943 and throughout 1944 by A. F. Posnette, Senior Specialist, W.A.C.R.I. Later Prof. E. E. Cheeseman sent a further eleven selections. All were planted in the Quarantine Station, Accra, at various times from 1943-45, and were transplanted to the field in 1945.

Twelve only came into bearing during the 1947-8 main crop season, among which were no West African Amelonado controls.

Experimental Procedure.

This was similar to the procedure dsecribed for First Progeny Trial samples.

RESULTS.

The results are expressd as the percentage of butter-fat in the unfermented, oven-dry nib. All experiments were carried out in duplicate.

TABLE 40.

Stand No.	Pod No.	Parentage.	Date of Harvesting.	Per cent. of Cacao Butter.			Comments.
				Light Petroleum extract.	Chloroform extract.	Total.	
			1947.				
961	T60	Parinari Nanay	11th Sept.	49·06	4·86	53·92	Upper Amazon crossed.
1316	T61	Nanay ...	11th Nov.	50·18	2·14	52·32	,,
1436	T72	Nanay x Iquitos	16th Sept.	49·08	5·68	54·76	,,
699	T73	,, ,,	30th Sept.	52·28	3·44	55·72	,,
414	T79	Nanay x Parinari	11th Nov.	50·78	3·58	54·36	,,
11	T87	Iquitos x Nanay	27th Oct.	50·22	3·84	54·06	,,
1331	T87	,, ,,	28th Aug.	51·80	2·70	54·50	,,
114	T12	Scavina ...	15th Oct.	50·32	3·64	53·96	Upper Amazon Illegitimate.
57	T56	Morona ...	11th Nov.	48·64	3·88	52·52	Upper Amazon Illegitimate.
1097	T26	Criollo ...	11th Nov.				Illegitimate = Trinidad I.C.S. No. 45.
—	—	Herrania balaoense.	31st Dec.	62·96	1·18	64·14	—
—	—	T67H.albiflora and T35H. balaoense.	31st Dec.	62·28	0·82	63·10	—
CONTROLS: Samples were those used as controls in First Progeny Trial Experiment.				AVERAGE = 52·08			

The results of greatest interest concern the Herranias. The percentage of extractable oil obtained gives them considerable economic significance and places them among the highest oil-bearing seeds in West Africa. A full investigation of this oil and also the alkaloidal content of the seed will be made when further samples become available.

SECTION V.

BOTANICAL AND HORTICULTURAL STUDIES.

1. Propagation by Cuttings.

Rooting and growth substances.

In a series of comparative trials with root-stimulating chemicals the following results established the superiority of β-Indolyl butyric acid for vegetative propagation under Tafo conditions.

0·5% Potassium Indolyl butyrate in Talc=85·9% rooted.
0·5% Potassium Indolyl butyrate as Dip=83·7% „
0·5% β-Indolyl butyric acid in Talc =86·6% „
0·5% β-Indolyl butyric acid as Dip =86·6% „
0·5% β-Naphthalene acetic acid in Talc =44·0% „
0·5% β-Naphthalene acetic acid as Dip =62·8% „
Hortomone A as Dip =76·3% „
Controls =68·1% „

Hardening rooted cuttings.

It has been found that glass-covered hardening bins give substantially better results than cloth-covered. In various experiments the proportion of cuttings successfully hardened in glass-covered bins was of the order of 80% as opposed to about 50% for cloth-covered. Plants must be kept close to the glass during hardening. When removed from the light the leaves quickly become chlorotic and drop.

The results of some experiments are given in Table 41.

TABLE 41.

Clone.	Hardening under Cloth. Number Potted.	Hardening under Cloth. Number Hardened.	Hardening under Cloth. Hardening Percentage.	Hardening under Glass. Number Potted.	Hardening under Glass. Number Hardened.	Hardening under Glass. Hardening Percentage.
ACU 85 E 1	20	3	15·0	63	55	87·3
U 7 ...	24	12	50·0	65	62	95·4
A 12 ...	12	7	58·3	28	24	85·7
O 2 ...	23	13	56·5	29	28	96·6
E 17 ...	38	24	63·0	39	29	74·4

Another contributing factor in successful hardening is control of the moisture content of the soil. Water is not required during the wet season but in the dry season the cuttings require water once, immediately following potting. Humidity is maintained by flooding the bottoms of the bins.

The time required for successful hardening has been reduced from 21 to 14 days. There is some indication that cuttings deteriorate if kept in the hardening bin longer than 14 days. All attempts to reduce the hardening period to less than 14 days have been unsuccessful.

2. Progeny Trials.

a. *First Progeny Trial* (*Planted* 1940).

In this trial the progeny of the selection E1 has again maintained the superiority it showed last year in regard to both yield and bean size. Self incompatibility has been noted among the selfed progeny of E1 and the proportion of self incompatible to self compatible is now being determined.

Wet weight records were taken. The pods from the seedlings of each selection were grouped and the beans bulked and weighed.

TABLE 42.

YIELDS OF BEST TEN PROGENY IN FIRST PROGENY TRIAL. MAIN CROP HARVEST, SEPTEMBER, 1947—FEBRUARY, 1948.

Selections.	No. of trees in bearing.	Total No. of pods.	Mean No. of pods per tree.	Total wet weight.	Mean wet weight per pod in ozs.
E 1	59	479	8·1	128 lbs. 10 ozs.	4·3
N 38 ...	45	378	8·4	82 „ 4 „	3·5
P 4/9 ...	38	295	7·76	62 „ 2 „	3·3
A 196 ...	36	298	8·27	59 „ 1 „	3·2
A 20 ...	42	272	6·47	57 „ 8 „	3·5
S 84 ...	41	268	6·53	49 „ 13 „	2·9
S 5	29	218	7·51	45 „ 5 „	3·3
P 4/6 ...	33	164	4·96	33 „ 5 „	3·2
A 121 ...	41	147	3·58	31 „ 0 „	3·3
Control ...	24	138	5·75	27 „ 2 „	3·1

The control is unselected West African Amelonado.

Table 43 shows the yield performance of the best five E1 seedlings for the period 1945-1948.

TABLE 43.

YIELDS OF FIVE BEST E1 SEEDLINGS, 1945-48.

Plot No.	Stand No.	No. of pods harvested 1945-48.	Total wet weight ozs.	Total weight dry cacao ozs.	Wet weight beans per pod ozs.
J 10/4	89	54	257·2	105·0	4·7
J 11/1	25	62	230·3	98·6	3·7
J 11/3	75	41	193·4	79·8	4·7
J 9/2	69	37	156·6	63·0	4·1
J 11/3	73	50	153·5	63·0	3·07

The J plots in the Progeny Trial are all situated in the best area of the trial. All seedlings within the area have made considerably better progress than elsewhere.

b. *Second Progeny Trial* (*Planted* 1942).

The number of trees in bearing increased by 50% during the past year. Yield figures per tree were considerably less than last year.

TABLE 44.

YIELDS OF BEST TEN PROGENY IN SECOND PROGENY TRIAL.

Selections.	No. of trees bearing.	Total pods harvested.	Pods per tree.
Tf 2	13	71	5·4
E 1	9	47	5·2
B 2	4	34	8·5
Tf 1	12	34	2·8
O 2	6	19	3·2
U 11	9	18	2·0
E 77	3	14	4·6
S 36	6	14	2·3
R 15	4	13	3·3
Control	3	8	2·6

It is interesting to note that the selection B2 is yielding a greater number of pods per tree than E1 in this trial, and that Tf 2 is outstanding in total yield.

c. *Fourth Progeny Trial* (*white bean experiment*).

This trial came into bearing for the first time. On harvesting, the beans were examined and the white beans segregated and sown in the nursery.

3. New Introductions.

a. *Pollen compatibility tests.*

Most of the cacao types that were tested proved to be self incompatible.

Two cacao selections, T19 and T54 (Ecuador type) were crossed with pollen of *Herrania* ? *Balaoense* and *H.* ? *Mariae*. All the set flowers shown in Table 27 developed into cherelles three to four inches in length but became diseased and were discarded.

TABLE 45.

CACAO X HERRANIA.

Selection.	Crossed by	No. Pollinated.	No. Set.
Th. Cacao (T 19) ...	*H.* ? *Balaoense* (T 59) ...	2	2
Th. Cacao (T 19) ...	*H.* ? *Mariae* (T 67) ...	11	4
(T 54)	*H.* ? *Mariae* (T 67) ...	12	6

No sets were obtained with the reverse cross, *Herrania* with *cacao* pollen.

Selfing and crossing of *Herrania* types was also carried out as follows:—

(*a*) All types were selfed and shown to be self-incompatible. The single set, obtained apparently from selfed T67 flowers, probably resulted from pollen contamination.

(*b*) Flowers of T67 (H. ? Mariae) were crossed with T35 and T59 (*H. ? Balaoense*) reciprocally.

(*c*) Flowers of *H. ? Balaoense* were crossed with *H. albiflora* reciprocally.

Results are detailed in Table 46. Viable seeds were obtained from 63 pods of *H. ? Balaoense* and *H. ? Mariae* crosses, and from three pods of *H. ? Balaoense* and *H. albiflora* crosses.

TABLE 46.

SELFING OF HERRANIA AND HERRANIA X HERRANIA CROSSES.

Selection.	Flowers selfed.	No. set.	Crossed by.	Flowers crossed.	No. set.
H. ? Balaoense (T 35)	55	0	*H. ? Mariae* (T 67)	37	19
H. ? Balaoense (T 35)	—	—	*H. ? albiflora* (T 58)	9	0
H. ? Balaoense (T 59)	65	0	*H. ? Mariae* (T 67)	4	1
H. ? Balaoense (T 59)	—	—	*H. ? albiflora* (T 58)	40	5
H. ? Mariae (T 67)	81	1	*H. ? Balaoense* (T 59)	19	14
H. ? Mariae (T 67)	—	—	*H. ? Balaoense* (T 35)	57	43
H. ? albiflora (T 58)	10	0	*H. ? Balaoense* (T 59)	10	0
H. ? albiflora (T 58)	—	—	*H. ? Balaoense* (T 35)	3	2

b. *Yields of New Introductions.*

These seedlings were introduced as beans in 1944 and planted in their present plot in 1945. During 1947 pods were harvested from 67 trees comprising 14 types. The highest yielding individual trees were T12/114 (Amazon Scavina), T79/414 (Amazon Nanay x Parinari) and T27/1009 (Criollo Nicaraguan) each of which bore seven pods.

c. *Losses in New Introductions.*

Losses during the year totalled 24 in number, composed of 15 Amazon, 6 Ecuador and 3 Trinitario types; 20 of the Amelonado controls died. None of these losses was due to swollen shoot disease.

4. New Planting.

New clonal plot.

A new clonal trial, covering approximately three and a half acres, has been laid out. Some 1,920 rooted cuttings composed of 20 different selections have been planted in a randomised block lay-out. Heavy losses were experienced during the dry season.

N38 plot.

A small plot covering one and a quarter acres has been planted with selfed seedlings of the high-yielding Nigerian selection N38 (called T38 in Nigeria).

SECTION VI.

MYCOLOGY.

Fungus Diseases of Cacao.

Work has continued on *Calonectria rigidiuscula* (Berk. & Br.) Sacc., *Botryodiplodia theobromae* Pat., and other fungi associated with capsid damage and dieback. Attention has also been given to pod diseases, including an obscure condition called "warty pod." Various minor problems have been investigated, including damping-off of cacao seedlings; one or more species of *Fusarium* appeared to be responsible for this trouble.

Calonectria Rigidiuscula (and other fungi associated with capsid damage).

Isolations.

From occluded capsid lesions. A large number of lesions deeply occluded in the trunks of mature trees has been sampled. The results were comparable with those obtained previously when isolations were made from younger material.

Cultures from material collected in Ashanti and the Western Province indicated that the flora of capsid lesions in these localities was similar to that at Tafo.

From occluded lesions following wounds. When collecting material for the work on old occluded capsid lesions, some lesions were found which appeared to have followed wounds, especially those made by cutlasses near the base of trees. Cultures showed that the fungi present were the same, and proportionately as common as those in occluded capsid lesions.

From alternative host plants. Isolations have been made from a number of plant species exhibiting insect damage, wounds or dieback. *Calonectria rigidiuscula* has been isolated from cankers associated with borer damage in saplings of *Anona muricata,* from recent *Distantiella theobroma* lesions on *Ceiba pentandra,* from internal lesions (apparently associated with dead lateral roots) in a root of *?Cola togoensis,* and from cankers following damage by *Helopeltis* sp. on a shoot of *Funtumia elastica.*

From surface of capsids. Capsids of various instars collected in the field were allowed to walk over the surface of nutrient agar slopes for about a minute. There was no evidence of either *Calonectria rigidiuscula* or *Botryodiplodia theobromae* in the resulting mixed growths. This affords another small piece of evidence supporting the view that the association of *C. rigidiuscula* with capsid damage is relatively fortuitous and by no means an obligate one. The absence of any form of the fungus in the salivary glands of capsids has already been demonstrated.

Inoculations.

Several experiments have been conducted involving the inoculation of spore suspensions of *C. rigidiuscula* into cacao seedlings by needle punctures. In one experiment, inoculations with *B. theobromae* were also made. Further work is necessary but many useful data have been collected and certain conclusions can be drawn.

C. rigidiuscula spreads fairly rapidly from artificially inoculated punctures, at least for the first three months. The extent of spread of *B. theobromae* is much less but is probably maintained for a longer period. *B. theobromae* produces rather larger lesions than those from control (un-inoculated) punctures which become naturally infected with various species of *Fusarium, Phoma,* etc., but in such cases the date of infection of the control punctures cannot be known, and to assess the ultimate effects it will be necessary to make observations over an extended period. Control punctures have frequently become infected with strains of *C. rigidiuscula* when the plants have been situated in standing cacao, but there is only one record of such infection in the case of plants on the alternative site which is over 100 yards from standing cacao.

The pathogenicity of four culturally distinct strains of *C. rigidiuscula* has been compared by inoculation into seedlings; the results did not indicate any appreciable difference in invasive capacity between the four strains.

Resistance trials.

Several experiments have been carried out to investigate the possibility of resistance to *C. rigidiuscula* being shown by certain types of cacao as rooted cuttings, budded clones and seedlings in the field. A wide range of Amelonado and Trinitario clones has been tested, as well as a random selection of Amazon, Criollo and Trinitario types among the recent introductions. The technique employed throughout has been the now established one of inoculating a spore suspension by a needle 0·5 cm. long. The length of the ensuing lesions is measured some weeks after inoculation.

Results to date have been inconclusive, but they have indicated that considerable variation in susceptibility to *C. rigidiuscula* exists among cacao varieties. No variety has shown marked resistance; but it could not be expected that a conspicuous degree of resistance would be shown to a fungus so unspecialised and so relatively weakly parasitic as *C. rigidiuscula.* Nevertheless, certain clones have consistently shown a much better performance than certain others, and the results from these experiments may be used in future selection work. Further investigations are necessary; the work done so far has indicated ways in which the methods can be improved so as to give more accurate results.

Miscellaneous.

The life history and cultural behaviour of *C. rigidiuscula* and other fungi has been studied. The pressing nature of more applied

investigations as well as the lack of equipment have precluded extensive investigations of these aspects of the problem, but some progress has been made.

Warty Pod Disease.

This disease of pods has been known for some years having been first described and named by Posnette in 1941. Local opinion is that its incidence at Tafo has increased considerably during the last several years. It has been found at various localities in the Eastern Province, also in Ashanti and the Western Province; it does not appear to be common in the Western Province, and the symptoms are not so severe there as those in the vicinity of Tafo. Observations have been made in the field at Tafo to determine the prevalence of the disease, and these will be continued to ascertain if it is actually becoming more widespread or severe.

An affected pod bears one to many protuberances, scattered apparently at random over the surface. When the pod matures, the warts become brown and a rapidly spreading rot extends from them. The rot sometimes affects the beans and may cause a pod to be discarded, so that the disease is of some economic importance. This may be judged from the following figures obtained from the Agronomy Division records. For the six months September, 1947 to February, 1948, warty pods formed approximately 3·5% of the crop. The percentage of the total crop which was discarded was about 15% while of the total number of warty pods harvested over 35% were discarded.

The fungus *Botryodiplodia theobromae,* and no other, has consistently been isolated from warts of all sizes and conditions, even from quite green ones on immature pods. It seems clear that a latent infection is involved, but nothing is yet known regarding the mode of entry of the fungus into the pod. It is possible that a sucking insect provides the avenue for invasion, but none of the sucking insects which are pests of West African cacao in their own right is considered to be responsible, since these all cause characteristic damage. Investigations into the etiology of this disease are continuing.

SECTION VII.

PHYSIOLOGY.

Field work on most of the projects cited in Dr. Goodall's programmee has been completed and computation of results is being carried out. In this report, mention is made of some of the projects from which early or preliminary conclusions have been reached.

Growth rate of cacao seedlings.

A field trial with five degrees of artificial (matting) shade was erected and the growth of Amelonado seedlings observed and recorded over a period of 30 weeks. The plants under full illumination soon showed marked pathological symptoms—dwarfing, leaf crinkling and necrosis, reduction in leaf area, death of apical buds and, eventually, defoliation. The same was true to a slighter extent of plants under 50% illumination but not of those under heavier shade. The experiment as originally envisaged was completed after plants had reached an age of 30 weeks, and the results are now being analysed. Further observations on a reduced scale are now being carried out following a partial redistribution of the seedlings among the various treatments to find out to what extent light-adaptation has occurred.

In the analysis of the results from one of the experiments on the variability of weight and growth of cacao seedlings it was shown that, under the conditions of the experiment, the net assimilation rate of cacao seedlings was remarkably low compared with other crop plants; the mean for the period between six and twelve weeks from planting for the 40 seedlings harvested at twelve weeks was 0·0627 gm./sq. dm./week, whereas the average of a wide range of temperate and subtropical crops is 0·551, while values of over unity have been recorded.

Individual tree yields in relation to overhead shade.

This work has proceeded satisfactorily and a final analysis is awaited. A preliminary analysis brought out the interesting fact that the total number of pods borne by a tree over nine years is linearly related to the square of the girth at the beginning of that period.

SECTION VIII.

EXPERIMENTAL PLOTS ON NATIVE FARMS.

Routine control of weed growth and shade has been effected on all sub-stations, and on the more advanced areas the cacao seedlings are now providing sufficient shade to inhibit weed growth. Grassy areas, which are generally associated with loss of fertility through food farming, have proved difficult on which to establish cacao, but the policy of intense shading by planting tree cassava at close intervals is proving effective.

Evidence as to the unsuitability of certain areas for cacao, or at any rate for its establishment, is shown in the failure for the third year in succession to bring the seedlings successfully through the dry season on these particular areas. Investigation has shown that there is only shallow soil overlying rock or impenetrable concretions in the majority of these patches, whilst in the remainder loss of fertility through previous heavy food farming is probably the chief factor.

Effective control of capsids by painting with D.D.T. emulsion has been attained on the four sub-stations established in 1945.

Seedlings infected with swollen shoot disease have been invariably associated with infected trees on the perimeter of the farm, or, in the case of Koransang, within the farm.

AKWADUM.

Routine weeding was carried out during the first nine months but was suspended in January.

Overhead shade has been reduced on the plots with cacao spaced at 10′×10′ by the removal of alternate *Leucaena glauca* trees, and tree cassava has been planted to provide shade at a lower level. Shade trees on the other treatments have also been thinned as the cacao itself develops its own canopy.

Forty-seven diseased trees were removed during the year, all on the perimeter of the farm, where infective material exists in the contiguous native farms and in the Pathology Division's Resistance Trial Area.

All cacao trees on the farm with the exception of one ¼-acre plot were painted with D.D.T. emulsion in August, 1947, and again in January, 1948. Control has been excellent, only occasional damage being caused by adult capsids.

The cacao received a severe set-back in December and January, as a result of drought, but made a rapid recovery with the February rains.

Nankese.

Growth of cacao has been excellent, except on small areas with shallow soil overlying rock, where losses during the dry period were so high as to justify abandonment. The effect of intensive planting of plantains, bananas and tree cassava as shade in areas which had been previously used for food farming is commencing to show dividends, with a suppression of the undesirable weeds and better conditions for cacao establishment.

Painting with D.D.T. emulsion in August and January kept capsid damage to a minimum.

The bark-eating caterpillars reported in February appeared again in July, but confined their feeding to forest tree seedlings.

Two seedlings infected with swollen shoot disease, both on the perimeter of the farm, were removed during the year.

Kukua.

Difficulty in the establishment of cacao from both seed and nursery transplants has again been experienced in the portions of the farm overlying rock and where the land had been heavily food farmed prior to acquisition, but whereas the cacao seedlings on the rocky areas were killed during the December-January dry period, many of those on the depleted soil recovered with the advent of the rains, although many lost the apical shoot.

Twenty-three seedlings were infected with swollen shoot during the year, eighteen near the perimeter of the farm and five grouped under a *Cola cordifolia* tree some 100 feet from diseased cacao. With the consent of the owners infected mature cacao contiguous to the boundary has been cut out.

Plots B and C, where control of insects and diseases is carried out, were painted with D.D.T. but as there has been little damage on Plot A, which is not controlled, there is not the same marked difference as on the other farms.

Adonkwanta.

Growth has been satisfactory during the period under review and with the exception of those planted in grassy areas, which had previously been food farmed, and in low-lying sandy areas in Plot B, all seedlings and recent transplants came through the dry period without loss.

Forty-six seedlings suffering from swollen shoot were removed from the protected part of the farm and fourteen on Plot A were left for observation. Of these, three have died and in no case to date have seedlings in the same piquet become infected.

The control of capsids by hand painting with D.D.T. emulsion has given spectacular results, 17·1% of the seedlings on Plot A being damaged and only 0·8% on Plot B.

The suppression of grass and undesirable weeds by the planting of additional shade has been encouraging.

KORANSANG.

The original swollen shoot outbreaks on this farm have now coalesced and can no longer be recognized as separate outbreaks. Of the 3,500 mature trees left after the initial cutting out in 1944-45 there are now 860 mature trees and 307 coppiced trees which have not succumbed to the disease. During the year 44 trees were coppiced as being suspected of carrying latent swollen shoot infection. Of the total of 351 trees coppiced 47 died before showing infection and eight were removed when symptoms became apparent on the new growth.

Infection in the seedling cacao planted among the mature trees has proved less than might have been anticipated, 72 seedlings being removed from an estimated total of 15,000, the majority of these being in the areas bordering on farms containing infective trees, over which the Institute has no control. Establishment and growth have been good and coppiced trees which have produced chupons with their own roots are extremely robust.

Capsid damage was controlled effectively by painting with D.D.T. emulsion.

A heavy infestation of bark-eating caterpillars occurred in May. They confined their attention to indigenous trees, with a preference for *Chlorophora excelsa* and *Cola cordifolia.*

SECTION IX.

AGRONOMY—TAFO STATION.

Old Station.

A. Cacao Crop.

The minor crop, harvested from May to August, was larger than the 10-year mean, but the total crop for the year was disappointingly low despite early indications of heavy pod setting.

Climatic conditions during the ripening period were particularly favourable to pod diseases and it was found necessary to resort to more frequent harvesting in order to escape the effects of the diseases. These measures were effective, as is indicated by the lower percentage of pods which it was found necessary to discard from the later pickings.

TABLE 47.

TOTAL CROP FROM ALL RECORDED CACAO (63·69 ACRES) ON OLD STATION, 1938-1948.

Season.	No. of pods harvested.	% of pods discarded.	Total weight wet beans.	% dry to wet wt. beans.	Yield per acre dry cacao lbs.
1938-39	775,065	15·82	127,468	43·8	808
1939-40	682,109	10·67	132,627	40·8	783
1940-41	706,443	8·43	140,161	41·4	788
1941-42	767,461	13·26	139,889	40·0	795
1942-43	621,724	10·54	155,388	43·1	749
1943-44	643,180	16·42	113,995	40·4	720
1944-45	593,217	14·69	108,037	40·8	690
1945-46	547,762	29·19	76,658	40·9	492
1946-47	368,859	5·51	58,564	44·5	409
1947-48	355,480	16·40	63,547	40·1	400
10-Year Mean	609,568	14·09	111,637	41·6	664

Owing to loss of trees from swollen shoot, and the inclusion of some plots in experiments, 23 of the 247 recorded ¼-acre plots of the Uniformity Trial on mature cacao are omitted from the following table, which gives the delivery of crop from 224 plots of ¼-acre and 31 plots of 1/16-acre, which have been recorded without a break since 1938.

TABLE 48.

DELIVERY OF CROP 1947-48 FROM 224 ONE-QUARTER ACRE PLOTS AND 31 ONE-SIXTEENTH ACRE PLOTS (57·94 ACRES).

Date of picking.	No. pods harvested.	% pods discarded.	Wet weight beans.	% dry to wet.	Av. yield per acre dry cacao.
1947					
May 5-13 ...	12,092	9·9	1,835·3	43·9	13·9
June 14-23 ...	11,345	7·4	2,301·7	38·2	15·2
Aug. 12-20 ...	33,583	26·0	5,696·9	31·6	31·0
Total Minor Crop ...	57,020	18·9	9,833·9	35·4	60·1
Sept. 2-20 ...	48,900	16·0	16,571·9	37·6	107·6
Oct. 1-25 ...	122,871	17·7	21,287·2	41·9	153·9
Nov. 3-12 ...	26,533	13·4	4,602·1	43·5	34·6
Nov. 18-Dec. 4	16,686	13·3	3,057·0	39·5	20·8
Dec. 11-19 ...	12,185	9·2	2,034·0	44·4	15·6
1948					
Jan. 6-21 ...	12,381	5·8	2,044·0	46·2	16·3
Total Major Crop ...	275,556	15·6	49,596·2	40·7	348·8
Grand Total ...	332,576	16·1	59,430·1	39·9	408·9

Distribution of Plot yields on 224 $\frac{1}{4}$-acre plots is given in Table 49. The medal class 201-400 lbs. per acre is as for the previous season.

TABLE 49.

DISTRIBUTION OF PLOT YIELDS ON 224 ONE-QUARTER ACRE PLOTS IN LBS. PER ACRE.

Yield Class.	Percentage of total number of plots in each class.			
	1944-45	1945-46	1946-47	1947-48
0– 200	5·8	8·5	16·5	13·4
201– 400	9·3	25·3	34·8	38·0
401– 600	23·1	35·1	26·8	36·2
601– 800	22·7	19·1	15·6	8·9
801–1000	24·4	8·0	4·9	3·1
1001–1200	7·4	3·6	0·9	0·4
1201–1400	4·9	0·4	—	—
1401–1600	1·8	—	0·5	—
1601–1800	0·9	—	—	—
Highest Plot yield in lbs. per acre...	1,661·52	1,251·6	1,527·6	1,002·68
Lowest Plot yield in lbs. per acre...	80·12	2·92	Nil.	Nil.

Loss of cacao trees.

Of the total of 975 trees lost on the Old Station 337 were suffering from swollen shoot disease, the balance of deaths being due to other causes.

Cacao Crop—New Acquisition.

The following are the details of cacao harvested from the New Acquisition :—

TABLE 50.

Pods harvested.	Pods discarded.	% pods discarded.	Dry weight lbs.	Pods per lb. dry weight.
695,413	108,355	15·6	54,430	10·7

As on the Old Station, more frequent harvesting was resorted to as a measure of control of pod diseases and routine sanitation measures were carried out in the areas under mature cacao.

B. Field Experiments.

Maintenance work on all field experiments continued with the application of mulch in the Rejuvenation Trial, and fertilisers on the N.P.K. Trial on young cacao. In neither the Rejuvenation Trial nor the N.P.K. Trial were significant results apparent.

Greater stress has been laid during the year on fostering natural shade. With the chemical control of capsids, all young cacao has made good progress.

During the year under review, a census was taken of "chupons" on the bearing cacao. On the completion of the census all shoots arising from the main trunk at more than 6" above ground-level were removed. The balance, which it is considered will become established on their own roots, have been protected against capsid attack by painting with D.D.T. emulsion.

The practice of clean weeding in patches of young cacao planted in open areas in the mature cacao has been abandoned and only undesirable weeds and climbers are removed by pulling. The natural shade is being supplemented by the planting of tree cassava, *Gliricidia* and bananas.

Some alarm has been felt at the loss of high-level shade due to deaths among the indigenous trees which form the canopy over the cacao, and the non-replacement occasioned by the farmers' normal practice of clean cutlassing under bearing cacao before harvest. To remedy this the Uniformity Trial Area of the Old Station has been marked out at 21′×21′ (100 stands per acre) and will be planted with suitable indigenous trees as seedlings become available from the nursery.

Natural regeneration of seedling shade trees will also be encouraged through all cacao.

The planting of the Uniformity Trial, Establishment Trial and Spacing Trial, using unselected West African Amelonado cacao throughout, was started in May and finished in June on the areas which had been prepared for planting in the previous year. Shade plants had become well established and conditions for planting were good. *Erythrina senegalensis* D.C. seedlings were transplanted at 40′×40′ spacing throughout all the experimental areas; in the Uniformity Trial *Antrocaryon micraster* A. Chev. & Quill. has been planted at the same spacing but alternate with the *Erythrina*.

Each experiment is as follows :—

Uniformity Trial.

Object.

The establishment of 10 acres of uniform cacao, in order to obtain yield data from which the optimum size of experimental plot may be determined.

Lay-out.

Cacao spaced at 8′×8′. Tree cassava and *Gliricidia* at 8′×8′ alternating with each other between the horizontal rows of cacao. Bananas at 16′×16′ planted in alternate rows of *Gliricidia*.

Soil.

Red sedentry, developed over Biotite Granite, Koforidua-Kukurantumi series.

Planting Material.

Unselected West African Amelonado cacao, seed sown at stake, three seeds per piquet. Germination of the seed was poor at the first planting in early April and piquets were replanted with seed in May. Growth from then onwards was satisfactory. Losses occurred during the December-January dry season amounting in all to 16·7% of the total seedlings.

Vacancies will be planted with seedlings of equivalent size during May and June.

Establishment Trial.

Object.

To ascertain within the limits of the experiment, the simplest and most satisfactory method of establishing cacao.

Lay-out.

The experiment consists of three groups, each of three treatments and each group of treatment being randomised in each of five blocks.

Cacao is spaced at 8′×8′.

Shade is uniform throughout the experiment and is planted as in the Uniformity Trial.

Treatments.

Group I—*Type of planting material.*

Treatment (*a*) Seed sown at stake, 3 per piquet dibbled in.

(*b*) Bare root nursery seedlings, holes just sufficiently large for planting.

(*c*) Basket seedlings, holes just sufficiently large for planting, minimum root disturbance.

Group II—*Method of Planting.*

Treatment (*d*) As treatment (*a*) above.

(*e*) As treatment (*a*) but in 2 feet cube holes filled with top soil.

(*f*) As treatment (*a*) but soil disturbance comparable with treatment (*b*).

Group III—*Efficacy of Mulching.*

All treatments as planted in treatment (*a*).

(*g*) Mulching with material from plot.

(*h*) An equivalent amount of mulch to (*g*) in addition to that from plot.

(*i*) No mulch.

Soil: As for Uniformity Trial.

Planting Material: Unselected West African Amelonado cacao.

Area of Experiment: 5 acres.

Percentage replacement is taken as the best criterion for judging success or failure of establishment in the first season and figures are given below:—

Treatments	(*a*), (*d*), (*h*) and (*i*) ...				21·2%	of	Treatment	Total
Treatment	(*b*)	...	...	...	115·0%	„	„	„
„	(*c*)	...	...	...	7·6%	„	„	„
„	(*e*)	...	...	...	34·5%	„	„	„
„	(*f*)	...	...	...	19·0%	„	„	„

Establishment of basket seedlings has been extremely satisfactory, as might be expected, whilst that of the nursery transplants has been poor. The high loss of seedlings in treatment (*e*) occurred during the dry season and can be attributed to the failure of the roots to get below the surface soil in the holes and into the moisture-bearing stratum of undisturbed soil. The figure of 115% for replacements in Treatment (*b*) implies more than one replacement per piquet.

Analysis of costs of the treatments, taking (*a*) as the index, are as follows:—

Treatment	(*a*)	100	Treatment	(*f*)	100
„	(*b*)	100·5	„	(*g*)	100
„	(*c*)	138	„	(*h*)	102
„	(*d*)	100	„	(*i*)	69
„	(*e*)	154			

High costs in (*c*) are attributable to the cost of baskets and in (*e*) to the difficulty of digging 2′ cube holes in newly cleared land abounding in unrotted tree roots.

SPACING TRIAL.

Object.

To investigate the optimum spacing at which West African Amelonado cacao should be planted, and the influence of the various spacings on establishment and eventually on yield.

Lay-out.

The experiment consists of seven blocks of eight treatments. The treatments are randomised within the blocks. Each treatment is surrounded by one guard row at the same spacing as itself, and by a row of bananas.

TREATMENTS.

Treatments.	Spacing in ft.	Plot size.	Trees per plot.	Trees per acre.
A	15′ × 15′	60′ × 60′	16	192
B	12′ × 12′	,,	25	302
C	10′ × 10′	,,	36	436
D	7·5′ × 7·5′	,,	64	774
E	7·5′ × 6′	,,	80	968
F	6′ × 6′	,,	100	1,210
G	5′ × 5′	,,	144	1,742
H	4′ × 4′	,,	225	2,722

Shade.

Tree cassava at 8′×8′. Permanent shade by *Erythrina senegalensis* at 40′×40′.

Planting Material.

Unselected West African Amelonado cacao, planted at 3 seeds per piquet. Growth has been good; despite severe tornado damage on two occasions, the shade has been effective.

Losses amounted to 13·9% of the total seedlings distributed as shown in the following table :—

TABLE 51.

Treatment.	Total seedlings in Treatment	Total vacancies in Treatment.	Per cent. vacancies to Treatment Total.
A 15′ × 15′	756	39	5·2
B 12′ × 12′	1,029	91	8·8
C 10′ × 10′	1,344	84	6·3
D 7½′ × 7½′	2,100	165	7·9
E 7½′ × 6′	2,520	166	6·6
F 6′ × 6′	3,024	175	5·8
G 5′ × 5′	4,116	231	5·6
H 4′ × 4′	6,069	306	5·0

Cost of planting increased as the spacing became smaller, due to the greater amount of clearing of the felled trees from the planting lines. It should be emphasized that this was desirous, only because of the experimental nature of the work, and that a farmer's plantation would not have to bear this increased cost.

Other Experiments.

Routine maintenance has been carried out on the following experimental areas controlled by the Pathology Division :—Trinidad Introduction Area, Multiplication of Introductions Area, N38 Progeny Trial, Clonal Yield Selections Trial.

During the year land has been prepared and nurse shade established prior to planting the Thinning Experiment (3 acres) and the 2nd Clonal Yield Selections Trial (10 acres).

Early Seed Production Experiment.

Two new sites for the Early Seed Production Experiment were selected during the year, each consisting of 100 trees.

Tafo Station, Maintenance and General.

Routine maintenance and sanitation measures embraced road repairs, repairs to permanent buildings, grass cutting in the habitation area, drainage and mosquito control by spraying buildings and oiling pools.

Food crops and vegetables have been grown on areas unsuited to cacao. Maize has been planted on 7¾ acres of the dam site to exhaust the soil prior to inundation.

A nursery to propagate forest tree seedlings was started and the nursery for hedge and ornamental and economic plants has been maintained.

The sheep flock has not increased so rapidly as in former years, due, no doubt, to the introduction of a large N.T. ram and a consequent increase in lamb and ewe mortality through difficult presentation at birth.

Timber purchases during the year amounted to 17,326 cubic feet valued at £3,794.

Meteorology.

Data are presented in Appendix I. Rainfall was well up on the 10-year mean, but the heavy rainfall in August and September was conducive to the rapid development of pod diseases.

O. J. VOELCKER,
Director of Cacao Research.

APPENDIX I.

METEOROLOGICAL DATA.

FIGURES FOR 1947 COMPARED WITH 10-YEAR MEAN.

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Highest Shade Maximum	10-year mean	90·8	93·2	93·4	93·1	92·0	89·1	86·6	86·1	87·8	89·6	90·3	90·2
Do.	1947 ...	93	94	95	94	93	90	86	87	88	92	92	90
Lowest Shade Minimum	10-year mean	59·3	61·6	66·0	66·1	66·6	66·7	66·5	65·2	67·1	66·7	64·9	61·7
Do.	1947 ...	55	66	62	62	63	68	67	67	68	66	58	60
Mean Relative Humidity (9 a.m. G.M.T.)	10-year mean	85·6	83·6	81·1	80·7	81·4	84·2	85·4	85·6	84·1	82·6	80·9	83·1
Do.	1947 ...	84·4	85·0	85·4	81·0	82·4	84·1	87·3	89·6	85·1	85·1	83·0	85·8
Mean Relative Humidity (3 p.m. G.M.T.)	10-year mean	52·6	49·8	52·0	54·9	59·3	65·0	65·9	64·5	70·0	69·3	65·0	61·1
Do.	1947 ...	50·8	58·4	60·7	62·8	67·7	70·0	74·6	78·3	81·3	69·2	66·9	61·9
Rainfall in inches	10-year mean	1·43	3·37	5·43	6·06	7·20	7·80	4·94	3·00	6·00	8·43	5·51	2·40
Do.	1947 ...	0·04	4·00	7·94	7·08	6·81	8·65	4·86	7·22	12·59	4·58	3·04	0·49
Number of wet days	10-year mean	4·0	7·5	11·9	11·2	13·5	18·5	12·7	13·4	17·2	17·5	11·3	7·0
Do.	1947 ...	1	15	16	10	10	23	13	25	26	16	12	5

ANNUAL RAINFALL FIGURES: 1938-47.

1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	10-year mean.
Inches 55·33	Inches 84·96	Inches 56·92	Inches 56·59	Inches 59·45	Inches 69·09	Inches 49·12	Inches 68·87	Inches 47·03	Inches 67·30	Inches 61·57

APPENDIX I (*Contd.*)

SUB-STATIONS.

Rainfall in Inches, 1947.

TABLE.

MONTHLY RAINFALL IN INCHES, 1947

Station.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Akwadum ...	1·44	4·93	5·79	2·32	7·22	4·79	5·63	3·05	7·78	3·57	6·08	0·57	53·17
Nankese ...	0·55	3·78	7·61	3·85	6·70	5·20	2·88	2·94	7·17	2·32	6·60	1·14	50·74
Koransang ...	0·53	3·5	8·24	7·29	7·54	5·00	2·98	4·25	5·76	8·09	5·69	5·11	63·98
Kukua... ...	0·65	4·29	7·22	5·63	7·60	4·72	2·06	5·08	4·69	6·31	6·61	1·78	56·64
Adownkwanta	0·36	4·12	11·98	8·90	6·60	6·76	3·18	5·47	9·49	3·51	6·83	1·31	68·41

ANNUAL RAINFALL IN INCHES.

Station.	1945.	1946.	1947.
Akwadum ...	52·3	44·07	53·17
Nankese ...	No. record.	39·98	50·74
Koransang ...		42·53	63·98
Kukua		45·84	56·64
Adownkwanta ...		45·01	68·41

FINANCIAL STATEMENT.

LIABILITIES.

	£	s.	d.
DEFICIT AND SURPLUS ACCOUNT	986,919	4	8
DEPRECIATION FUND :—			
Motor Vehicles £1,798 0 0			
General Equipment 188 0 0			
	1,986	0	0
	£988,905	4	8

ASSETS.

	£	s.	d.	£	s.	d.
GOLD COAST GOVERNMENT :—						
Repayment	400,000	0	0			
Less : Advances ... £110,000 0 0						
Pension Contribution... 2,249 14 11						
Balance from previous year 213,162 14 11						
	325,412	9	10			
				74,587	10	2
SUNDRY DEBTORS :—						
Staff Advances	1,352	2	7			
Staff Subsidies	841	10	0			
Other Debtors	111	15	0			
				2,305	7	7
STORES, at cost :—						
Timber	2,947	13	10			
Sundry Building Materials	2,072	2	10			
				5,019	16	8
INVESTMENTS, at cost :—						
£200,000 3% Savings Bonds 1960/70...	213,001	0	0			
£200,000 2½% National War Bonds 1954/56	206,376	0	0			
£200,000 3% War Loan 1955/59 ...	215,701	18	0			
£200,000 3% Savings Bonds 1965/75...	218,375	16	0			
				853,454	14	0
POST OFFICE SAVINGS BANK DEPOSIT...				1,986	0	0
CASH :—						
In Hand—Imprest Account	200	0	0			
At Bank of British West Africa Ltd....	7,111	0	10			
Joint Colonial Fund Deposit	44,240	15	5			
				51,551	16	3
				£988,905	4	8

(*Sgd*) O. J. VOELCKER, *Director.*

We have audited the above Balance Sheet with the books and vouchers of the Institute and have obtained all the information and explanations that we have required. Subject to our Report of even date attached hereto we are of the opinion that the Balance Sheet sets forth a true and correct view of the financial position of the Institute according to the best of our information and the explanations given to us and as shown by the books of the Institute.

ACCRA,
14*th June*, 1948.

(*Sgd.*) CASSLETON ELLIOTT & CO.,
Auditors.

APPENDIX III.

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